Aide-Memoire

TO

THE MILITARY SCIENCES.

PART F. G. H. I. K. L. M.

CONTAINING

*** THE BINDER *is requested to cancel this page of 'Contents'—the 'List of Plates'—and the 'Notice of the third Part,' on the completion of the Work.*

LIST OF PLATES.

* These Plates were given in the second Part, and should be inserted as above when the volumes are bound.

NOTICE

OF

THE THIRD PART OF

THE AIDE-MÉMOIRE.

THE Editors of 'THE AIDE-MÉMOIRE TO THE MILITARY SCIENCES' regret the delay that has occurred in the publication of the Third Part, or rather the First Part of the second Volume.

The delay has arisen in some measure in collecting materials from Contributors quartered in distant parts of the Empire, and in collating and preparing the subjects for the press: these difficulties have been increased by the adoption of the alphabetical arrangement, which, however perfect in the end, has rendered it necessary to wait for such portions of the work as could not be passed over.

The Editors again solicit notices of errors and omissions which may appear in the three Parts now published, that they may be corrected or supplied in the next or concluding Part.

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AIDE-MÉMOIRE.

F.

FORTIFICATION, FIELD.

"La fortification de campagne simple dont l'exécution est ordinairement confiée a l'Officier qui est chargé de leur défense, cette premièr espèce de fortification doit faire l'étude des Officiers d'Infanterie."

"La fortification de campagne composée, elle ne peut-être dirigée que par des Ingénieurs et elle doit faire partie de leur service."

The first part comprehends works executed principally with the Pick, Shovel, and the Felling-axe, by cutting and carving the means on the spot, and thus preparing the ground for Temporary Defence.

The second part includes those works which require some consideration, the calculation of time, and resources within a limited distance; and the application of some of the Rules of Permanent Fortification: these works are executed with care and with greater means than the first, particularly if they are destined to stand the vicissitudes of the seasons.

And in order to render the subjects of Field Fortification as concise as possible, and to avoid repetition, those treated of in other parts of the 'Aide-Mémoire' will be expressed in Roman characters, as ABATTIS, BLOCKHOUSE, DAM, &c.; to which reference must be made for details.

PART I.*—SECTION I.

a. The following description of tools and stores would be found more or less necessary, where *temporary works* are to be thrown up, and they should be furnished in the required proportions to any detachment whose duty it might be to strengthen and afterwards defend a post.

b. They are classed in three divisions, that their separate uses may be apparent.

Class 1. Field Service Tools.

Shovels Pickaxes Felling-axes Bill-hooks	For sinking trenches, forming breastworks, felling timber, making abattis and obstructions, &c.

Class 2. For Houses, Walls, &c.

Sledge-hammers Hand-borers Crow-bars Saws Augers Spike-nails	For forming loopholes, breaking through walls, preparing timber for barricades, stockade-work, &c.

Class 3. General Service and purposes of Defence.

Sand-bags Rockets Small shells Hand-grenades	The sand-bags for blocking up windows, and forming loopholes, &c. The rockets and shells for defence of houses and intrenchments.

c. The proportions of these necessary to be demanded will of course vary with the description of work which may be anticipated.

* By Lieut.-Colonel Jebb, R.E.

For example, in throwing up earthen-works in an open country, a pickaxe and shovel for every man that could be employed on the breastworks would be wanted. If an ABATTIS could be formed, and there were fences to be cut up and levelled, one-third of the men would be advantageously employed with felling-axes and bill-hooks. In a case where houses were to be placed in a state of defence, walls would have to be broken through for making loopholes, and windows, doors, and passages to be barricaded: here crow-bars, hand-borers, sledge-hammers, spike-nails, and saws, would be required in greater proportion than spades and pickaxes.

Sand-bags are included as being very useful for many purposes, such as protecting men when firing over a parapet or breastwork; quickly blocking up the lower parts of windows, &c.; in each case, loopholes being arranged by disposing them as shewn in fig. 31.

A man will carry one hundred empty sand-bags, weighing about 60 lbs., each of which will contain a bushel of earth, and when *full* they are *musket-proof.*

Rockets,* small shells, and grenades, are mentioned as being very powerful and attainable auxiliaries in the defence of posts and houses; and one great advantage of them is, that any body who has common sense may use them, or at least be instructed in the requisite precautions in a few minutes.

d. A certain *division of labour* must also be attended to, and a man should always have a tool put into his hand that he has been accustomed to use: carpenters should therefore be employed where saws and axes are wanted; miners and blacksmiths where walls are to be broken through; labourers where the spade and pickaxe come into play. Those who never handled tools of these descriptions would be most usefully employed in collecting materials. It would be well also to select such men for the first tour of duty, as patrols and sentries, and to employ the best workmen in overcoming the greatest difficulties, which are usually found in the commencement. A little foresight will not be misapplied in considering these points.

e. It is useful to obtain the assistance of the inhabitants in executing works of this description, and an Officer should always have authority to enforce their attendance, and to pay them in proportion to their exertions. They should also be required to bring with them whatever tools they can best use, or that are most wanted.

SECTION II.—BREASTWORKS.

a. A general idea may be formed of the quantity of work that can be done in a given time, and of the proportion of cover that may be obtained in that time, by adopting different sections when throwing up the earth, by referring to Plates I. & II. figures 1 to 7, and the corresponding estimates, which are calculated on the following data.

First. That on an average, an ordinary labourer will dig out *one cubic yard,* or *twenty-seven cubic feet of earth an hour,* in middling soil; and continue to work at that rate for eight hours or more. And secondly, on the supposition that

* As an illustration of the use of rockets, it may be mentioned that on one occasion, during the late war in Canada, an American gun-boat took up a position which enfiladed a situation where a bridge that had been destroyed was being re-established; from whence she kept up a fire that bid fair to stop proceedings. Artillery could not be brought up, but luckily rockets were thought of, and a few were obtained from the rear. The second that was fired entered her bows, and caused so many casualties, that the 24-pounder was reduced to silence; and it was only by a shift of wind that the boat was got off, after being driven close in shore, and many of the remaining men being killed or wounded by a light company that ran into the water up to their pouches, in the hope of taking her.

EACH MAN HAS SIX FEET IN LENGTH TO EXECUTE, which distance enables him, when at work with others in a line, to use his tools with perfect freedom.

It should be observed, that the first of these data admits of considerable latitude, and A CUBIC YARD AN HOUR, which is a convenient average to remember, is the least work that ought to be expected, unless in a very strong hard soil: in a light sand not requiring much use of the pickaxe, an indifferent labourer would remove two cubic yards an hour with more facility than he would one in difficult soil; and, bearing this in mind, the nature of the soil on which a military post might be situated would frequently have a great influence in modifying the details. With regard to the supposed DISTANCE OF SIX FEET FOR EACH PORTION, it is not to be considered *invariable*, but *convenient*. Men may be set to work as near as 4 feet from each other, but the time gained is not in proportion to the diminished distance, for they will be too crowded to work with ease, and they will be liable to injure each other, especially at night. Still, however, there is no doubt that any given quantity of work would be completed in less time by disposing workmen at 4 or $4\frac{1}{2}$ feet than at a greater distance. On the other hand, when only improving the natural advantages offered by banks, fences, &c., the working parties might be distributed at much wider intervals than 6 feet; having reference to the time in which they could execute any given portion. For instance, a man might possibly convert 20 or 30 feet of a hedge into a good breastwork in three hours, when he could not execute 6 feet in length, of one equally defensible, in the same time, that required to be artificially created on a level field.

b. Before entering further into the details, it may be right to mention as a general rule, that in almost all cases where trenches are required, it is essential that the means of getting out of them with facility, both to the front and rear, should be preserved by leaving slopes or steps for that purpose. Thus on some occasions it is desirable they should offer no impediment to a forward or a retrograde movement, but that troops should be able to march straight over them when necessary. In the trenches, however, which will now be brought more immediately under consideration, and which are designed not only to provide cover, but to be vigorously defended when attacked, the chief object of making a step in the rear would be, that the defenders, instead of waiting for the assailants in the bottom of the trench, might step out after giving their last fire, and thus interpose a fresh obstacle between them and their enemy, besides placing themselves in a better attitude for resistance.

c. Fig. 1 represents the section of a small trench, and the parapet or breastwork that has been formed by throwing the earth up in front of it. The trench is $2\frac{1}{2}$ feet deep, and the same width, having a rough step of one foot broad in the rear. The earth thrown out will make a parapet of a height nearly equal to the depth of the trench, without taking any precautions in building it up at a steeper slope than it will stand at of itself: we will assume that it is 2 feet high, which will make a total of $4\frac{1}{2}$ feet from the bottom of the trench. A man, therefore, though he can reach to fire over the top of the parapet, has to stoop to be wholly concealed or covered by it, and it therefore affords as little protection as is worth the trouble of considering in this place.

The solid content of the excavation, from which the probable time it will take to execute may be determined, is found by multiplying the depth and breadth of the trench together, for the superficial measure or area of the section, and that product by the length each man has to do. Here $2\frac{1}{2}$ feet multiplied by $2\frac{1}{2}$ feet is equal to $6\frac{1}{4}$ feet, and that product multiplied by 6 feet, which we have assumed to be the portion allotted to each workman, gives $37\frac{1}{2}$ cubic feet. The step is 1 foot broad and 1 foot deep, and being 6 feet as before in length, there will be 6 solid feet more to

add, making altogether $43\frac{1}{2}$ cubic feet for the solid content of the mass of earth that has been removed.

Now if a man is only supposed to dig out 27 cubic feet in an hour, it will take him rather more than an hour and a half to remove $43\frac{1}{2}$ cubic feet on level ground.

Plate I. *d.* Fig. 2 affords more cover, for the top of the parapet is 6 feet above the bottom of the trench. The best way of executing such a profile would be to sink a trench 3 feet deep and 3 feet wide, and to throw the earth about 2 feet in front of it; so that in the progress of the work, when the trench was found to be too deep to stand in and fire with convenience over the top of the parapet, a little step might be cut out of the solid left in front, for a banquette, as shewn shaded in the section; and another step of the same description in the rear would complete it as far as it went. The steps might be 18 inches wide, and the same depth.

The area of this section is nearly 14 feet, the trench itself being 9 feet, and the two steps $4\frac{1}{2}$ superficial measure, which, multiplied by 6 feet, the length of the portion allotted to each workman as before, gives 84 cubic feet, or about 3 cubic yards, for the solid content of the excavation; and therefore, under the presumed data, it would be completed in three hours: still, however, it will be observed, that it offers no impediment in itself to an enemy, and men could only be drawn up in single file for its defence, from there not being room for more.

e. A trench of the dimensions shewn in fig. 3 might be completed in five hours on the presumed data, and being roomy enough to dispose men in double files for its defence, and high enough to screen and cover them, may be considered as large as is necessary for merely fulfilling those conditions; for if more time could be devoted to strengthening a post, or if other circumstances were favorable, it would become a consideration whether some profile of a different form could not be substituted with advantage for such as only afford cover without opposing any obstacle to the advance of a hostile force.

f. Fig. 4 is a form of breastwork that might be adopted for obtaining cover in rocky or marshy situations, where a ditch or trench could not be made deeper than 1 or 2 feet; and if there were plenty of men, they might be set to work in two lines, and get it completed in half the time it would otherwise take, either by sinking on each side of the proposed situation, or by arranging the men in two lines behind it, as shewn in the figure, where the situation for the second line of workmen is shewn at *a*.

To work on both sides the breastwork, which is the quickest way, it would have to be considered what breadth of ground the breastwork with its slopes to the front and rear would stand upon, and what breadth the banquette and berm ought to be. These particulars being determined, two parallel lines would be roughly traced on the ground with pickets at the required distance. The workmen would be drawn up facing each other on these lines, and would work backwards, throwing the earth into the space between them, which some spare men would form into the breastwork.

Here sinking only 2 feet, the breastwork must be raised $4\frac{1}{2}$ feet to obtain cover. Suppose the slope on the inside is made steep by building it up with sods, or other materials, so that it only occupies 18 inches of level ground. The outside slope being left to find its own level, will require a base equal to its height, or 4 feet 6 inches; and if we add 2 feet for the thickness of the breastwork at the top, it will cover 8 feet of ground. Then if the banquette is made 2 feet broad, and the berm 1 foot, the distance between the two lines of workmen will be altogether 11 feet.

Under the second supposition, if the two lines of workmen were drawn up one behind the other, and both working to the same front, the distance between them might be from 4 to 7 feet, according to the depth.

The level of the ground in this instance forms the banquette or step to fire from. There will be about 5 cubic yards in 6 running feet of breastwork, and as there are supposed to be a double number of men at work, it ought to be finished in two or three hours.*

g. This mode of executing work may also be adopted with advantage in other cases when time is an object, and there are plenty of hands, or when it is of importance to strengthen and give height to breastworks in particular situations. But as far as this profile is concerned, it is to be observed, that it would afford cover to an enemy when he got at it, without opposing any impediment to his advance, which it is always very desirable to avoid.

h. Should the ground be rocky or very hard, as in a road or street, cover may perhaps be more expeditiously obtained by raising a breastwork from rubbish or materials brought to the spot in baskets, sand-bags, or barrows, than in attempting to sink at all. Different expedients are shewn in Plate II. figs. 11 and 12.

i. Having thus far detailed the most expeditious modes of providing cover for men, it may now be worth while to consider whether in securing that advantage for the defenders, you cannot at the same time add another, in opposing an *obstacle* to an enemy, by excavating a ditch in *front* of the breastwork in place of making a trench in *rear* of it. A ditch to stop people at all, should be at least 8 or 9 feet broad, and 6 or 8 feet deep; in more Permanent Works it would of course be considerably more.

I. *k.* Fig. 5 shews the general dimensions which such a profile might have. The ditch, it will be observed, is of a triangular form, the area of which, for calculating the quantity of earth to be moved, will be found by multiplying its breadth by *one-half* its depth, that is, 9 feet by 4 feet, which gives 36 superficial feet; and that multiplied again by the length of the portion each man has to execute, (we will here say 4 feet, as the breadth is considerable,) will be $36 \times 4 = 144$ cubic feet, or about 5 cubic yards in each portion of 4 feet; which, considering the increased labour arising from a greater depth than has hitherto been contemplated, would not probably be completed in less than six hours by the same workmen. Some spare men, probably equal to one-half the number employed in the ditch, would also be required for ramming the earth, and forming the breastwork. Thus on 100 feet in length there would be twenty-five men working in the ditch, and twelve additional, making in all thirty-seven; whilst in the common trench-work, which has hitherto been under consideration, only about seventeen workmen have been shewn to be necessary for every 100 feet.

l. A profile, such as that now under discussion, therefore requires not only longer time to execute, but double the number of men; and it would not seem advisable to undertake it, unless there were a reasonable probability of its being completed before an attack could be made; for if an enemy came upon it when in an unfinished state, it would be almost useless, and the labour, which if otherwise applied would have secured at least good cover, would thus be thrown away. Still, however, the advantages it offers should not be lost sight of in situations where a determined stand is to be made, and on very accessible points, or to shut up roads or streets, &c., even if the rest of an intrenchment were differently arranged. As far as the means of resistance is concerned, it is obviously of more advantage to have a ditch in front of a breast-

* When from circumstances the depth of a trench or ditch is very limited, the probable time it will take to form a breastwork out of them, is more readily determined by estimating the content of the *mass* to be raised, than the *excavation*, as in the preceding cases, because the breadth of the latter will probably be irregular.

work than a trench in rear of one; and the only point to be determined is, whether there is *time* and *means* for executing it: and it is on this point that an Officer will have to exercise his discrimination, when he has carefully considered the various circumstances of his situation, which will have influence upon it; and which have already been detailed.

m. Such a profile may further be much strengthened by planting a row of palisades in the ditch, or even by driving stakes in and sharpening them, or making what may be called a perpendicular abattis, by planting brushwood upright in the bottom, with
Plate I. the ends sharpened, as shewn in figs. 5 and 6.

An expeditious way also of adding to the difficulties of an assault, is shewn in fig. 7, where common hurdles or gates, rails or brushwood, laid on the ground soon after commencing the work, and their extremities buried under the parapet, may be made use of: the earth underneath them, shaded dark in the figure, should be cut away,
Plate II. when the ditch has been sunk to its full depth, fig. 7.

Short posts laid horizontally every 8 or 10 feet in the same situation, and long rails or a chain afterwards nailed to them, would be a ready expedient: the ends should project about 2 feet over the ditch, and stand at least 6 feet above the bottom of it.

n. It is to be observed that in all the foregoing cases, only a *minimum of cover and means of resistance* has been sought for in a *minimum of time.* It has been shewn *what can be effected in a few hours;* it may so happen, however, that time is given to improve upon the profiles described, as would be the case if an advanced post were held for some days in succession, and each Officer in command had done what he could towards it. These improvements would consist in strengthening the breastworks, making the ditches deeper and wider, and planting more redoubtable obstructions; and such opportunities must never be thrown away, as the means of defence, and the security afforded, will be augmented in proportion.

o. It may be remarked, that such breastworks as offer little or no impediment of themselves to an enemy, if well laid out, permit the defenders to charge over them in line if they wish it, and still possess one of the principal attributes of any work, which is that of *screening them from previous observation.* But a forward movement from those that do offer an obstruction, must be through an opening, and therefore on a narrow front.

Now the space between a breastwork and an obstruction placed in front of it is ground belonging to the defenders, which, if circumstances permit, should be disputed; and as an enemy would probably be in some confusion in forcing his way through such obstruction, a favorable moment would doubtless occur for making a sudden charge, which, supported by a good flank fire, ought to be successful. These advantages should never be lost sight of in arranging the General Plan of Defensive Works, and determining the profiles they shall have. The salient angles of the intrenched lines are the points most open to attack, and it will be observed that the profile of the lines, terminating in those salients, has a ditch in front, which presents more or less of an obstacle; whilst the profile of the line adjoining the battery in the centre, is only that of a trench for providing cover, because it is not in a situation open to attack.

COMMUNICATIONS THROUGH BREASTWORKS, &c.

p. When an opening or passage is required through a breastwork or stockade, it must be arranged so as to be easily closed and defended. These objects may be in some measure secured by disposing the lines in such forms as are represented in figs. 8 and 9, and providing rough strong gates, CHEVAUX-DE-FRIZE, or something of

the sort, for quickly shutting them up. When houses are concerned, as in a street, the BARRICADE may extend quite across, and a communication be made round the end of it, by breaking through walls, as shewn in fig. 10.

SECTION III.—DEFENCE OF HEDGES, ROADS, &C.

a. In the foregoing explanation of the Details of Breastworks, an attempt has been made to shew the least possible time in which decent cover could be obtained when working on a level plain, unaided by any advantages of ground and situation; and it must be confessed it is rather a damper to one's ardour to find, that five or six hours of hard work may be calculated upon, before any thing like comfort can be obtained under such circumstances; and that the people who should be kept fresh for resisting an attack, are likely to be worn out by their exertions in preparing for it.

This, however, happily, is by far the worst side of the picture, for with a moderate share of luck, some little slope or broken ground will offer itself; and some hedge or ditch, bank, wall, road, or wood, will be found, either placed exactly as if it were there on purpose to be defended, or a plan could readily be arranged for turning it to some account. An eye is put into a man's head to be made use of, and it only requires a little previous exercise of that organ, to see all these natural intrenchments and local advantages in almost every possible circumstance of ground and situation.

b. An endeavour will be made to explain by the Sketches in the annexed Plates, in reference to the Second Class of Works, the simple means which are most in use, and which appear adapted for improving, and deriving advantage from such local objects as are most commonly met with, in the hope of shewing, that by the *judicious application of a very little labour*, a serious, and in some cases an almost insurmountable obstruction, may be formed. (See Plates III. IV. and V. figs. 14 to 30.)

Fig. 14 represents a hedge on the top of a steep bank, which has been cut down within 2 feet of the ground: the branches have been carried to the front as an obstacle, and two small steps have been made on the slope, the one to load on, the other to fire from.

Fig. 15 is supposed to be the same situation, but defended in an opposite direction. The hedge might be felled as an obstacle, leaving the stumps 2 feet high to screen the men; or it might be cut thin and left standing, if it were considered better. The slope in front is made steeper, and a little hollow is made to fire from, kneeling.

Fig. 16.—A ditch on the side of the enemy is supposed to have been deepened, and the earth and sods formed into a breastwork on the reverse of the hedge; where a small trench has also been made, to obtain additional cover.

Fig. 17.—The same, fronting the other way; the hedge felled as an obstruction, or cut thin, so as to give no cover to an enemy, and left standing. The ditch deepened to 6 feet, and a small breastwork made from the earth thrown out of it, and from a trench in the rear.

Fig. 18.—A double post and rail. Brushwood is interlaced in the front rail as an obstacle, and a breastwork is made leaning against the other to afford cover.

Fig. 19.—A bank, with double ditch. One ditch has been deepened, and the other partly filled up.

Fig. 20.—The edge of a quarry, or steep bank: a very defensible situation.

Fig. 21.—A wet ditch, or brook. The breastwork made from a trench in the rear.

Fig. 22.—A road. Both fences felled as obstructions, and a breastwork placed for defending them.

Fig. 23.—A hollow road, arranged in a similar manner.

Figs. 24 and 25 are profiles on a bare steep bank, to shew the way of obtaining cover in such situations.

c. It may be remarked, that as obstructions placed under a close fire in front of Temporary Works are essential to their being properly defended, it will be a consideration whether a hedge would be more conveniently converted into such an obstruction, as in fig. 17, or be made to form part of a breastwork, as in fig. 15.

d. Before setting his men to work, it would be necessary that an Officer should have a notion of the time it would take to execute his projected defences: for this purpose he might pace the whole length of his proposed line, and then, by forming an idea how long it would take one man to finish a certain portion of it, say 4 or 5 yards in length, of deepening a ditch, scarping a bank, or felling a fence, he would see whether the number of men at his disposal could complete the whole in a given time, and would curtail or enlarge his plan accordingly, and distribute his men at intervals of 4 or 5, or 7 or 8 yards, as the case might be; for it is impossible to offer any defined Rules which shall apply where circumstances are ever varying.

A stick may be cut for measuring out the portions, and stakes may be driven in for explaining the slopes and the general form of the profile that is required.

SECTION IV.—DEFENCE OF WALLS.

a. Walls are readily made available for purposes of Defence by loopholing them, the mode of doing it varying with their height and situation.

b. It is a General Rule, that loopholes must be so placed, as that an enemy, if he succeeds in rushing up, shall not be able to reach so as to make use of them; for it is clear, that if he stands on the same level as the defenders, the loophole would be adapted for serving the convenience of *both* parties, which is not their object.

To obviate this inconvenience, loopholes should be placed 8 or 9 feet above the ground on the outside; but on the inside, the banquette or step, from which the defenders are to fire, should not be more than about 4 feet 6 inches below them, which may be assumed as a convenient height for the purpose, as already explained in treating of Breastworks. A portion of the wall also, not less than 18 inches high, should be left *above* the loopholes, where there is opportunity, for the purpose of screening the men's heads when giving their fire.

c. These points are attainable in several ways, and circumstances must decide which is the most convenient: for example, if a wall were 10 feet high, the loopholes might be pierced within 18 inches of the top, and a temporary stage might be made of casks, waggons, ladders, &c., or an earthen banquette might be thrown up inside for the people to fire from, (Plate V. fig. 26.) And in cases where a very determined resistance was to be made, a second row of loopholes might be arranged, as shewn in that figure. On the other hand, if a wall were only 6 feet high, the loopholes might be pierced 4 feet 6 inches above the level on the inside, and a ditch cut on the outside to obtain the requisite height, which arrangement would save the trouble of making any banquette, (fig. 27.)

d. The quickest way of making a loophole is to break a wall down from the top to a depth of 2 feet, in the form of a narrow fissure, at intervals of 3 feet or more apart; and as this can be done with common pickaxes if there are no better tools at hand, it will generally be found a more convenient mode than cutting them through the wall, when time is an object. Such loopholes will appear as shewn in fig. 28: it will be seen that they are not quite so safe to fire from as others, but this inconvenience may be partially remedied by filling the upper part with a stone, a log of wood, a sand-bag, &c.

e. If a wall should be very low, or there were not time to make loopholes, a piece of timber, or the trunk of a tree, supported by a couple of stones, on the top of it, would be a ready expedient, and men could fire from the opening under it, as in

V. and VI. fig. 29. Or sand-bags, if they were at hand, might be laid there, having loopholes between them, (see fig. 33.) Or large stones or sods might be placed there in default of sand-bags. A man of resource would seldom find any difficulty in appropriating something to his purpose.

f. The temporary loopholes that are made in walls or buildings are not of course confined to any regular form; they are merely holes to fire through, made in the required direction, and so as to see the ground from within a few yards of the wall or building in which they are pierced, to the extreme range of a firelock, affording also the opportunity of firing a little to the right and left.

To secure these points, the absolute dimensions will vary with the thickness and height of the wall: the width of the hole outside, however, need not exceed about 3 inches; but the width inside should, if possible, be equal to the thickness of the wall.

g. The best tools for breaking loopholes through brick-work or masonry are short iron bars, steeled at the head, called hand-borers. They are held in the proper situation by one man, and struck with a sledge-hammer by another. But if people are employed who have not been accustomed to the use of such tools, they would perhaps get on better each man with a crow-bar, which any body can handle. A beginning might be made on the face of a wall with a pickaxe, which would very much facilitate proceedings. The time it will take to break through a wall will be best determined by a trial on the spot; for materials are so very various, it might lead to erroneous conclusions, were any attempt made to state a general average. Much also would depend on the tools and workmen, which adds to the difficulty of offering any precise data.

h. A wall exposed to the fire of artillery will not afford good cover, in consequence of the splinters that will fly from the materials whenever it is struck; but if time admits of it, this inconvenience may in some measure be obviated, by sinking a trench a few yards in the rear, and throwing the earth up against the *inside* of the wall; or a ditch may be sunk on the outside, and the earth be thrown over. The trench is best, as it will give additional protection to the men; but the ditch may be required as an obstacle, or to give height to the loopholes, and therefore, as usual, circumstances must decide what is best to be done. It is not contemplated that there would be opportunity for giving this embankment sufficient thickness to make it shot-proof, but most of the splinters would bury themselves, if it were only 3 or 4 feet thick.

SECTION V.—STOCKADE-WORK.

STOCKADE-WORK may be substituted with advantage for Breastworks, when there is timber to be had in abundance, especially if it can be covered from the fire of artillery. It has this advantage over earthen-works of very small profile, that if made high enough, it is not easily got over, and therefore in itself it opposes an obstacle to an enemy, which they generally do not. (See Plate V. figs. 32 to 34.)

Stockade-work may be made with the rough trunks of young trees, cut into lengths of 12 or 14 feet, and averaging not less than from 10 to 15 inches in diameter. They should be firmly planted upright, in a narrow ditch, 3 or 4 feet deep, either close together, or with intervals of a few inches for firing through. The interstices in either case should be filled up to a certain distance, with shorter pieces of timber to protect the men, and the loopholes should be arranged with the precautions adverted to before.

A banquette or step will generally be required on the inside; and a ditch, and any other obstacle on the outside, that can be made in the time, will add to the difficulties

of an assault. In defending a stockade, the means of stopping up any partial breaches which may be made by artillery should be at hand, and a flank fire across the front is very essential, as it will be obvious that were an enemy to succeed in rushing up to it, he would be under cover from the direct fire of the loopholes.

PART II.*

SECTION I.—GENERAL PRINCIPLES.

a. It is not necessary to the Professional Officer to give definitions or the details of the component parts of Field Fortification, or of the tools and materials used, which have been explained in Part I.: it is sufficient to give the general principles on which these works, applicable to Part II., are constructed.

b. The extent should be in proportion to the number of men assigned to the defence.

c. That the approaches should be well seen, and, if possible, taken in flank, (see fig. 63, Plate IX.;) and all obstacles forming part of the defence should be within 200 yards for musketry fire and 500 yards for field-pieces.

d. The salients, when possible, should be thrown into inaccessible hollows, marshes, or rivers, if not flanked by a cross fire, as explained in par. *c.*

e. That flank defence for the security of the ditch is rarely applicable to this description of field fortification, for want of depth of profile, or sufficient relief, to secure those men who line the parapets from destruction from the fire of the collateral flanks, or works, if detached: hence all auxiliary protection, such as PALISADES, ABATTIS, or CHEVAUX-DE-FRIZE, (see Plates VIII. and XIV. figs. 54 and 55, and 94 and 95,) should be seen from the parapet of the work they are intended to protect; and consequently ditches should be considered as the *déblai* only, or means of furnishing the requisite quantity of earth for the parapets, banquette, and glacis.

f. Hence the ditch of a field-work is no security and rarely any obstacle.

g. Musketry fire is the legitimate defence, and the point to be gained is to keep the attacking force under its fire, either from front or flank; a detention of a few minutes being sufficient in most cases.

h. *Artillery* seldom forms part of the defence of this description of field fortification; the work is generally to cover and secure the artillery, principally from cavalry, the field-pieces being planted for some especial purpose, as in fig. 63. (See also 'Battery,' Sect. XIII.)

i. Field-works seldom stand alone; they generally form a system of defence, supported by troops; when isolated, they should be constructed with care.

k. All field-works should be fortified outwardly, making the interior slope of the parapet the trace of the work, otherwise the area within will be frequently found too confined.

l. The necessary interior space should not be less than 20 square feet per man, within the banquette, and 220 square feet for each field-piece.

m. Time, although not of primary importance, is essential to the Professional Officer, to avoid attempting beyond his means, and the object of the works to be constructed.

n. In the execution of a work, sufficient command should be given to the profile, so that an enemy outside on the crest of the ditch or glacis should not see into the work.

* By Colonel Lewis, C.B., R.E.

o. With the above precautions, the shape of the work is of no consequence, provided it is adapted to the ground, object in view, and time necessary in construction; and the several diagrams are given in Plates IX. to XIII. to assist the Officer in the hurried moments of execution.

SECTION II.—DESCRIPTION OF FIELD-WORKS.

a. Redans. Figs. 64, 65, and 68, serve for the security of advanced posts, or couvre-portes to works and buildings, and they are sometimes termed flèches; and when they have flanks, as fig. 64, they are called lunettes: these works are only used when supported by others.

b. Redoubts are enclosed works, without flank defence: when constructed with flanks, they are called forts. Redoubts, as in figs. 64, 67, 68, and 69, may be either square, circular, or polygonal.

c. Square Redoubts should not have their interior side less than 60 feet; but if less than 100, there is not sufficient space for a reserve for the defence. A BLOCK-HOUSE, or DEFENSIBLE GUARDHOUSE, is the best support to a square, with the sides placed opposite the salients, as in fig. 67. In connection with other works they are frequently arranged as in fig. 64.

d. Circular Redoubts are rarely constructed, but fig. 68 is a notable example of their utility, taken from a French work on the banks of the Zezere River, in Portugal.

e. Polygonal Redoubts are most convenient for enclosed works without flank defences, as they can be suited to the contour of the ground, and they afford more interior space: fig. 69 is an example, with an inner work to serve as a keep.

f. Field Forts consist of star forts, bastion forts, and polygonal, with re-entering angles *en tenaille*.

g. Star Forts.—The construction of these involve much trouble, and are rarely applicable to Part II.: when used, they should not be constructed upon a polygon whose sides are less than 100 feet or more than 200 feet. These works are especially adapted to isolated spots, (see fig. 66.)

h. Bastion Forts are not well calculated for field-works, and when constructed, the flanks should have at least an opening of 100° with the line of defence. They are best applied as TETE-DU-PONT, for the construction of bastion forts is difficult; requiring exterior revetments, there is loss of space, and they are not easily adapted to the ground.

i. Polygonal Forts will be found applicable in preference to any nicely constructed work analogous to Permanent Works. Polygonal forts are generally suited to the ground, (see figs. 70 to 73, and 84.) Fig. 71 is a trace of a work constructed and defended by the British troops in 1794, the capture of which led to the evacuation of Toulon.

VI. and *k. Epaulements* for cavalry and connecting other works, as in fig. 64, are constructed in open plains, where there is no irregularity of ground to cover cavalry, to protect them from a cannonade, as explained in figs. 43 and 44: to the latter is a banquette for musketry, and thus converting the epaulement into a detached curtain.

SECTION III.—OBSTACLES AND AUXILIARIES OF DEFENCE,

such as ABATTIS, BARRIERS, BLOCKHOUSES, CHEVAUX-DE-FRIZES, DAMS, FOUGASSES, FRAISES, PALISADES, STOCKADES, and TROUPS-DE-LOUP, are treated of under their several heads in the 'Aide-Mémoire:' these are artificial; there are many natural resources besides, such as inundations (see Article 'DAM'), marshes, and pre-

cipitous ground, and the latter may be improved by scarping the face, the slopes, and means of QUARRYING, (see fig. 90, as applicable to the security of the front and flanks of field-works,) and may be termed local; whilst the artificial obstructions, or auxiliaries of defence, must depend upon the nature of the means within a moderate distance.

SECTION IV.—TIME REQUIRED TO EXECUTE FIELD-WORKS, DISTRIBUTION OF THE WORKMEN, AND NUMBER OF MEN NECESSARY FOR THE DEFENCE, AS APPLICABLE TO PART II.

a. Time required.—Find the number of cubic yards in the ditch or ground to be executed, and divide the amount by the number of shovels to be employed, which will give the number of hours,—the nature of the soil giving the number of shovels required. For the sandy soils, three-fourths will require shovels; in clay, two-thirds; and in hard gravelly soil, one-third of shovels is necessary in the excavation. A reserve of tools should always be provided in the event of the ground changing after the surface is removed, but with a crow-bar the soil may be pretty accurately ascertained.

b. Distribution of Workmen.—Divide the length in feet of the centre of the ditch of a given work by 4, and it will leave the number of workmen to be employed in the first row, and half that number for the second row; and the first number again to adjust the earth and revet the parapet: if the ditch is narrow, only one row will be requisite.

Example: Suppose the ditch is 120 feet, which divide by 4,—gives

30 for the first row,
15 for the second,
30 for the parapets,
—
75 total number of men to be employed.

c. Number of Men for the Defence of a Work.—First, if open, or supported by collateral works, give 2 men for each linear yard of interior parapet. Secondly, if isolated, give 2 men + $\frac{1}{3}$ for a reserve, provided the work has not less than 160 yards of parapet. If isolated, and of less capacity, it is presumed that it can only be partially attacked.

The men for defence should have the front rank placed on the banquette, and the second behind on the terreplein of the work, to load: if the men are allowed to step up on the banquette and fire, they will do so at random.

SECTION V.—TRACE, PROFILE, AND CONSTRUCTION OF FIELD-WORKS.

a. Trace.—Previous to this operation, it will be found convenient, and eventually a saving of time, if the project of defence is put on paper by the Engineer, and submitted to the Officer commanding the troops, to obtain his signature, if approved; for works treated of in the Second Part of Field Fortifications should be duly considered. This preliminary being settled, and the tools collected, the following articles will be necessary for tracing the work.

Hambro' lines.
Pickets, 18″ long.
Mallets.
10-feet rods.
Mason's level and bob.
Bevels adapted to the slopes of parapets.
A straight edge.
Two short lengths of scaling ladders.
Profile stuff.

The last should be made from 3-inch deals, cut across into battens $1'' \times 3''$, and a certain quantity into poles 3 inches square for uprights.

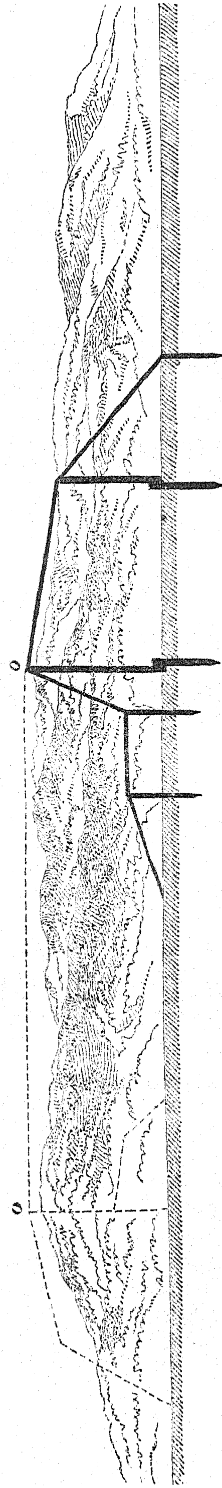
Thus provided, the works should be traced out, as explained in Article 'BATTERY,' with the Hambro' line stretched upon that corresponding with the entire crest of the parapet (o) in the annexed diagram; and from this the dimensions marked out by pickets firmly driven into the ground, transferring the works from the plan approved; when probably some modification will be found necessary, when the tracing is completed, by marking it on the ground with a sharp spade, called spit-locking.

b. Profile.—The question of relief having been decided upon in reference to command, or DEFILADE, or as a security against artillery, or only against musketry,
II. the dimensions will be found in figs. 45 to 53: the poles must be driven into the ground, corresponding with the angles of the work, and the battens nailed to them, as explained in the diagram.

The under surface of the battens give the dimensions of the work, by which means the uprights only will be lost, and buried in the ground. And in order to judge whether the interior of the work is sufficiently covered from without, or defiladed, if in the vicinity of high ground, a cord should be stretched from profile to profile, o to o, (see the diagram, corresponding with the crest of the parapet.)

c. Construction and Execution of Field-Works.—The *remblai* and *déblai* having been calculated from one of the profiles chosen in the figures of the Plates on Field Fortification, the materials taken from the ditch should be so placed that the work may be raised to the whole breadth of the parapet and banquette and of rampart, and should be carried up in even courses of about 18 inches or 2 feet, and well consolidated with the earthen rammers to the level of the banquette, when arrangements must be made for revetting the parapet.

d. Revetments of Field-Works.—These are generally necessary to the interior slope of the parapet, and sometimes to the exterior, to give the necessary solidity, and prevent it crumbling away by the effects of the weather, otherwise the parapets would lose their proper dimensions. The interior slopes may be lined with FASCINES, GABIONS, or HURDLES, as likewise the cheeks of the embrasures, but artillery in these works are generally *en barbette*, or as is explained in Article 'BATTERY,' Section XIII. There are resources to be found on the spot occasionally, such as *sods*, also *old building stones* and *bricks*: the latter could be built up within 2 feet of the crest of the parapet, and then completed with sand-bags or sods, or earth well beaten. Sun-



Profile of Field-Works.

burnt bricks will serve in some climates, and last many years. When the exterior slopes of the parapet require to be revetted, the *branches* and *trunks of trees* will serve, laid horizontally, as also *logs of wood* squared or unhewn, trenelled together, where timber is abundant.

SECTION VI.—GATES OR BARRIERS, DRAINING AND COMMUNICATIONS.

a. The *entrance* should be always well traversed and palisaded, and secured with gates or BARRIERS, as explained in the latter Article.

b. The *draining* and keeping the works clear of water is an essential consideration in the construction of this description of field fortification, to preserve them for a certain time, so as to drain the ditches as well as the interior of the work; and for a good method of doing so, see Article 'DRAIN.' The interior of the work should be also levelled and dressed towards the several drains.

c. The *roads* and *communications*, although last mentioned, should be at an early period attended to, as facilitating the several operations in the construction of works. The formation of ROADS must also have reference to whether required as the means of communication for the troops and artillery, or as connecting the works by a covered passage, where the earth will be thrown up outwardly as a parapet or glacis, always leaving the interior slopes sufficiently gentle to allow the infantry and cavalry to advance or retreat over them, (see Plate XIV. fig. 96.)

SECTION VII.—CONCLUSION TO PART II.

This division of Field Fortification, of which the works are supposed to be designed and executed by an Engineer or Staff Officer, is written to remind him on the spot, ready for action, and not as an Essay on Fortification, which would exceed the object of the 'Aide-Mémoire,' and also to give the general principles, leaving the proper application to the ground and circumstances to the person intrusted with this important charge—having in consideration always one point, to observe if there is not some principal feature to serve for the key to the post or position, and which, if fortified with care and skill, may make it difficult, and sometimes impossible, to overcome; such as a flèche or redoubt, with artillery placed in a marsh, or on a summit of a precipitous ground, or covered by an impenetrable wood, which may take in reverse the advance, or flank the approaches to the post or position.

APPENDIX.

MEMORANDA RELATING TO VARIOUS DETAILS OF FIELD-WORKS AS THROWN UP IN FRONT OF LISBON.*

(Plates XI. XII. XIII. XIV.)

"Les principes des fortifications de campagne ont besoin d'être perfectionés: cette partie de l'art de la guerre est susceptible de faire de grands progrés.

"Les fortifications de campagne sont toujours utiles—jamais nuisibles, lorsqu'elles sont bien entendues."—*Conversations de Napoleon, par Montholon.*

Workmen.—The manual labour of the lines was performed by the peasantry of the country and two regiments of militia. The former were obtained by conscription, and were relieved weekly; the latter worked as a permanent duty. The peasantry were paid six vintems per day as labourers, and twelve vintems per day as mechanics, and the militia at one-third those rates.† Subsequently, as the work increased and

* By Major-General Sir John Jones, Bart., K.C.B., R.E.

† A vintem is 5·4 farthings.

lengthened almost into a permanent occupation for the peasantry, their rate of wages was augmented to ten vintems per diem for labourers, and sixteen for artificers, the militia continuing to be paid at the original rate. In August, 1810, when more than 2500 men were working in a body at Alhandra, and the ordinary supply of the town would not furnish sufficient provisions for such augmented numbers, the Officers of Engineers took upon themselves to make requisitions on the neighbouring districts for bread sufficient to supply each workman with a pound per day, and saw that the value was regularly stopped from the men's wages at the end of the week. In the winter of 1810 and 1811, when the country was totally exhausted of provisions, this system was improved into a regular supply of a pound of biscuit per man, issued by the British Commissariat, for which three vintems per day were deducted from the wages of the peasantry.

Superintendence.—The number of Officers of Engineers employed on the lines never exceeded seventeen at the same time, viz., eleven British, two Hanoverian, and four Portuguese; and the number of their own soldiers never exceeded eighteen rank and file; but they had the assistance of more than one hundred and fifty soldiers of the line, principally artificers, selected from the regiments at Lisbon. The latter were under the charge of a Captain stationed at Mafra, and a Subaltern at Alhandra, but were divided into parties of two and three each throughout the whole extent of the country to be retrenched. In some of the districts a Subaltern Officer of Engineers, with that small number of English soldiers, utterly ignorant of the language, directed and controlled the labours of a thousand or fifteen hundred peasantry, compelled to work, many at the distance of forty miles from their homes, whilst their own lands lay neglected, and no Portuguese ever attended of higher authority than a cabo, equal, according to military classification, to a serjeant; nevertheless, during a twelvemonth of this forced labour, not a single instance of insubordination or riot occurred, and the great quantity of work performed, should, in justice to the Portuguese, be more ascribed to regular habits of persevering labour in those employed, than to the efficiency of the control exercised over them.

Mode of Payment.—On commencing the lines, the Officers of Engineers were made public accountants, contrary to the regulations of the Service, which strictly prohibit it; and they had, in consequence, to take charge of large sums of money (all in silver) and make the weekly payments of the labourers' wages.

Every moment of the Engineers' time being devoted to the works, and no Officer having a secure place to lodge the cash, nor any competent person to keep his accounts, many were considerable losers by this duty, and the active service of the senior Officer of each district was altogether lost one day in the week whilst settling with the workmen, each of whom individually received and signed in triplicate for his 4*s.* 1¼*d.*, which useless formality rendered the payment of fifteen hundred or two thousand men the labour of many hours.

After some months, the impolicy as well as injustice of making the Engineers paymasters becoming apparent, an Officer of the Commissariat, with efficient clerks, was named for that duty, and made a regular round of the districts, paying the workmen on lists prepared and certified by the Engineers. In a similar manner, during the latter periods of the war, in carrying on works in detached situations, the Officer of Engineers was relieved from the responsibility of being a public accountant, by the duty of paymaster being allotted to an Ordnance Clerk or conductor of stores, who received a sum of money to cover the intended service from the Commissary-General, and disbursed it on the order of the Engineer in charge of the work.

Materials, Stores, &c., how obtained.—All materials, stores, implements, &c., were purchased by the Commissary-General on requisition from the Commanding

Engineer, and the Officers in charge of the several districts only gave receipts for the quantities delivered to them, being in no way responsible for or consulted respecting the price.

Lieut.-Colonel Fletcher had a general authority from the Commander of the Forces to make these demands on the Commissary-General, and when he gave over the charge of completing the lines to Captain John T. Jones, and made him responsible for the future expenditure, he also transferred his authority to order materials, &c., which authority, so delegated, was found efficient. In like manner, Captain Goldfinch was subsequently invested with similar delegated powers and responsibility, whilst retrenching the position of Almada; and, generally speaking, each Officer, when employed in charge of a distinct work, had authority to make demands on the nearest commissariat station.

The gunpowder used for blasting during the formation of the scarps of the lines, the quantity of which was very considerable, also that used for mining the bridges and roads, was obtained from the Ordnance Commissary at Lisbon as wanted, on requisition addressed to the Commanding Officer of Artillery.

When mining was ordered in situations distant from any artillery dépôt, it was at first customary to draw cartridges from the nearest brigade of guns; but as this was invariably found to be a source of vexation to the Artillery Officers, a supply of gunpowder was latterly transported with the Engineers' stores, with cases ready prepared for given charges.

Trace of the several Works.—The redoubts were made of every capacity, from that of fig. 74, limited by want of space on the ground it occupied to fifty men and two pieces of artillery, to that of fig. 89, for five hundred men and six pieces of artillery, the importance of the object to be attained being the only guide in forming the dimensions. Many of the redoubts first thrown up, even some of the smallest, were shaped like stars (figs. 82 and 86), under the idea of procuring a flank defence for the ditches; but this construction was latterly rejected, it being found to cut up the interior space, and to be almost fallacious with respect to flank defence, the breadth of the exterior slopes being in some cases equal to the whole length of the flanks so obtained, as in fig. 86. Even when, from the greater size of the work, some flanking fire was thus gained, the angle formed by the faces was generally so obtuse, that it demanded more coolness in the defenders than ought reasonably to be expected, to aim along the ditch of the opposite face; and further, this construction prevented the fire of the work being more powerful in front than in rear.

Plate XI.

Plates XII. and XIII.

In order to decide on the proper trace of a work, it is necessary to consider whether its object be to prevent an enemy establishing himself on the ground on which it is to be placed, or whether it be to insure a heavy fire of artillery on some other point in its vicinity. In the first case, every consideration should be sacrificed to that of adding to its powers of self-defence by flanks or other expedients. In the second, its powers of resistance are secondary to the establishment of a powerful offensive fire, and its trace cannot be too simple. Latterly, the shape of the redoubts was invariably that most fitted to the ground, (figs. 74, 75, 77, 78, 83, 84, 85,) or such as best parried the enfilade fire or musketry plunge of neighbouring heights, care being taken to present the front of fire deemed necessary towards the pass, or other objects to be guarded; and such will generally be found the best rule of proceeding.

s XIII. XIV.

This recommendation, however, is not intended to apply to isolated works of large dimensions, and more particularly to those considered the key of any position. No labour or expense should be spared to render such works capable of resisting the most furious assault, either by breaking the parapet into flanks, or forming a flank defence in the ditch; for the experience gained in the Peninsula shews that an

unflanked work of even more than an ordinary field-profile, if skilfully and determinedly assaulted, will generally be carried; for instance, Redoubt Renaud, Forts Picurina and Napoleon, &c. Nor does the serious evil of curtailing the interior space, which renders any breaks in the outline to procure flanks so objectionable in small works, apply to works of large dimensions; for it must be recollected, that in similar figures, whilst the length of the outline increases only in the simple ratio of the double, triple, or quadruple, the interior space or surface increases as the square of their like sides. Under this view the great work on Monte Agraça (fig. 72) must be considered as very defective, the flank defence being confined to an occasional break of a few feet in the trace, caused by a change of direction in the contour of the height, whilst the interior space is more than doubly sufficient for the number of its allotted garrison to encamp.

Interior and other Defences.—This work, however, had some of its most exposed salient points, or those most easy of access, or most likely to be assaulted, cut off by earthen lines of parapet, steeply revetted externally, and so traced as to serve for traverses to the interior. It had also three or four small enclosed posts formed within it; and the work at Torres Vedras (fig. 73) had each of its salient points formed into an independent post. These interior defences and retrenchments were intended to guard against a general panic amongst the garrison, which would necessarily be composed in part of indifferent troops, and also to prevent the loss of the work by the entry of the assailants at any weak or ill-defended point. Such interior lines to rally on are absolutely essential to the security of a large field-work. They serve as substitutes for the BLOCKHOUSE or tower, placed in the interior of all well constructed permanent earthen-works, and merit far more attention than they generally receive.

The small circular wind-mills of stone, which were frequently found occupying salient knolls selected for the site of advanced flèches, were readily converted into admirable interior posts of that nature; and many mills situated on the elevated points of the main defences were made to add greatly to their security by a similar conversion. (Figs. 87, 88, 89.)

Redoubt No. 109, occupying a very important, and very exposed point in advance of the position of Oeyras, was deemed of so much value, that being commanded by a height between 600 and 700 yards in its front, in order to insure some power of resistance after its parapet and scarps should have been destroyed, its artillery dismounted, and its interior ploughed up by a cannonade from the height, a gallery, loopholed for reverse flanking fire along the ditch, was formed behind the counterscarp at the salient angle of the front faces, and a communication made to it from the interior, under the bottom of the ditch. The soil being of a hard chalky substance, which stood without support, fixed the adoption of this means of defence in preference to the ordinary caponière, which requires so much labour. (Figs. 83 and 97.)

The parapet of 109 was also cut *en crémaillère* to throw a musketry fire on the salient angle next the heights, and to screen the defenders of its left face from the enfilade fire of the heights. This mode of indenting the parapet, however, was not thought a good measure generally, it being found to add very much to the labour, and to abstract from the direct fire of the work an equal quantity to that it threw in a different direction; besides making the defence of the parapet rather complex for militia. Therefore, latterly, in those redoubts where any particular trace was not imperious, it was always preferred to make an additional face to the work, than to leave a salient angle so acute as to necessitate such extra support; and at Almada, this principle was carried so far as to render the contour of some of the redoubts almost circular. (Figs. 79 and 84.)

Situations of the Works.—Many of the redoubts were placed on very elevated situations on the summit of steep hills, which gave them a most imposing appearance; but it was in reality a defect highly prejudicial to their efficiency and defence, for the fire of their artillery on the object to be guarded became so plunging, as to lose half its powers; the musketry could not be made to scour the face of the hill sufficiently; and during the night both arms became of most uncertain effect.

The domineering situation of the redoubts, however, gave confidence to the young troops which composed their garrisons, protected them from a cannonade, and screened their interior from musketry, unless fired at a high angle, and consequently at random. These considerations perhaps justified the unusual elevated sites selected for most of the redoubts on the lines, though they cannot induce an approval of them as a general measure. Indeed, the ill consequences arising from height of situation was so strongly felt on the lines, that on very elevated points, particularly at Monte Agraça, in order to command the face of the mountain, flèches, or small redoubts, were established in front of the main work, (fig. 72,) on the projecting knolls which afforded the best flanking points. These advanced batteries were made of the same strong profile in front as the redoubts, and their gorges were equally secured, except that the rear parapets were formed as mere screens, so as not to give cover against the fire of the main work; and for the same object, the counterscarps of the rear ditches were sloped into the plane of the parapets of the commanding work. Even these flèches, though nearly doubling the garrison, saw the face of the hill less perfectly than the main work alone would have done, if placed on a height of a moderate and more regular ascent, which shews that very elevated situations for works are seldom to be preferred.

At some points, where it was deemed likely that the troops would act in combination with redoubts occupying the summits of very elevated knolls, flèches or field batteries were prepared for the field brigades in the best flanking or enfilading situations, much lower down on the face of the hill. This seems the most judicious mode of occupying a height as a field position, when the artillery can be placed under the effectual musketry fire of the redoubt; but on these lines, it being impossible to foresee which part might or might not be occupied strongly by troops, it was made a rule to put no artillery in battery, except within works capable of defending themselves. At some points, where space could not be obtained within the redoubts, the guns were placed on a lower advanced level, connected on its flanks with the defences of the redoubt, (fig. 80.) Some of the flank defences were limited to one or two guns, which could only be justified by the difficulty an enemy would find in passing the object they fired upon. It ought to be received as a general rule, that no flank can be formidable to infantry which does not contain at least three pieces of ordnance; and even to render a flank of three pieces very destructive, it must be in a situation of tedious approach, or in a work which cannot be run into.

Profiles.—The profile of the several works varied on every face and flank, according to its liability to be attacked or cannonaded, the only general rule enforced being, that all ditches should be at least 15 feet wide at top and 10 feet in depth, and the crest of the parapet have at least 5 feet command over the crest of the counterscarp.

No parapet exceeded 10 feet in thickness, unless exposed to be severely cannonaded, and few more than 6 or 8 feet; and some, on high knolls, where artillery could not by any possibility be brought against them, were made of stone or rubble, less than 2 feet in thickness, to gain more interior space, and allow full liberty for the use of the defenders' bayonets. Many of the rear enclosures, when supported on precipices, were merely screens; and in some few cases, on the position near Ribaldiera,

they were left to the precipice itself, (fig. 76.) The rear of advanced flèches, and other small works, situated within good musketry fire of the main defences, were generally closed with a very open but strong stockade, (figs. 87 to 89.)

In elevated situations, many of the banquettes were raised within 4 feet of the crest of the parapet, it being the rule to fix the level along each face at such height as would admit of the musketry plunging down the face of the hill, or at least seeing some yards of the glacis.

The exterior slopes were made greater or less, according to the tenacity of the soil; but it was found, after the first winter, that no slope cut through the natural ground had sustained itself at a greater angle than 45°, and in made ground the exterior slopes were washed away at that angle. Indeed, in consequence of the heavy rains in southern climates, it is almost essential to form some kind of revetment to works to keep them defensible during winter; and in 1811, most of the exterior slopes of the works of the lines were retained with dry stone walls. To insure an efficient system of drainage should always be a principal consideration with an Officer on commencing a work. Some redoubts, deeply excavated, with the view to screen the defenders, particularly Nos. 101 and 102 at Oeyras, from neglect of this precaution, literally filled with water, in September, 1810; and the labour of forming drains, to keep their interior dry, was little less than that of constructing the redoubt.

The interior of the parapets were retained with fascines or sand-bags: the former stood perfectly well, except that those originally made, being composed of the smaller branches and twigs, became, during the summer, so readily combustible as to be considered unsafe; and latterly, only the larger branches, completely divested of their leaves and twigs, were worked into fascines, intended for interior revetments. The sand-bags rotted, and burst after the first winter.

A drawing is given of the profile of several of the works in different situations (figs. 91 to 97): that of the redoubts on the heights of Almada (fig. 95) deserves particular attention, as those works stand in situations open to be violently cannonaded, and the hills forming the position are such as are most frequently occupied with works; and the profile was fixed after the experience gained in making the lines: it was as follows:

	ft.	in.
Height of interior crest of parapet	7	0
Height of parapet above banquette	4	3
Thickness of parapet	14	0
Berm	2	0
Breadth of ditch at top	16	0
Depth below surface of ground	12	0
Crest of glacis below crest of parapet	5	6

In the profile of lines of flanked works, in low situations, where the interior space was not limited, the crest of the parapet was generally fixed at 10 feet above the level of the ground, for the purpose of a better command in front, and better covering the troops; and this height was thought to be the best adapted for attaining a good defence with moderate labour. Even with this elevation, no covered-way was formed to any line, but the crest of the glacis was kept 6 or 6½ feet below that of the parapet.

The redoubts of the lines being mostly thrown up as secure emplacements for guns, and to procure an open field for the fire of their artillery being the principal object attended to in their construction, they were mostly placed on the summit of the heights they occupied, so that each face might have a full command of the ground in its front, or of the point it was intended to protect; but, in other situations where

the object of a redoubt was merely to prevent an enemy occupying a particular spot, it was, wherever practicable, constructed on an inclined plane on the reverse of the height, so that only its most salient point, or, perhaps, its front faces, rose over the crest of the hill, (fig. 98.) This defilement gives the work considerable protection from cannonade, and causes the front parapet to cover the rear lines and the defenders far better than if constructed on a horizontal plane, and should generally be adopted in situations where an enemy cannot establish batteries in its rear, and invariably in the construction of lunettes or flèches in advance of a fortress, as beyond the advantages above mentioned, it causes the interior of the work to be completely seen from the place.

In this construction the rear enclosure, whether palisades or a wall, should be made of a strength to resist light howitzer shells pitched over the parapet, but not so strong as to afford cover against the heavy guns of the place.

Stores and Provisions.—In each redoubt wholesome casks were provided, and placed in security, to contain four quarts of fresh water per man for the calculated garrison, besides the tubs with water for the use of the Artillery; and a dépôt of intrenching tools was also provided, in the following proportions:

	Shovels.	Pickaxes.	Felling-axes.
Works for 400 men	10	6	3
„ 300 „	8	4	2
„ 200 „	7	4	2
Smaller	6	3	2

Monte Agraça, proportion for 1500 men.

Magazines.—The magazines were formed of splinter-proof timbers, about 10 inches by 8, placed at an angle between 45° and 50° against a substantial traverse; and wherever an efficient drain could be made around them, their floors were sunk one, two, three, and even four feet below the level of the interior of the work; which excavation, and the relative height of the redoubt with respect to the ground in its vicinity, served to regulate the length of the timber, so as to have the top of the magazine sheltered from direct fire.

The magazines were lined internally with plank, and strengthened externally with 2 feet of earth in sand-bags, over which tarpaulins were spread; and, thus protected, these magazines were found sufficiently dry.

Platforms.—The platforms, as originally laid down, consisted merely of a plank for each truck, but during the summer and autumn of 1810 they were all replaced by platforms of ordinary construction. Many of the redoubts being on undulating heights, and the guns being mounted on extremely low carriages, it required undeviating attention to keep the front of the platform on a sufficiently high level to insure the guns clearing the intermediate swell of the height, so as to strike an object at the foot of the slope. In such situations, the eye will frequently attain an object which the gun on its lower level will not.

Palisades.—The palisades in the ditches were mostly young fir-trees from 4 to 5 inches in diameter, roughly pointed, and fixed 3 or 4 feet into the ground, with a riband very low down, and, when the ditches were broad, much nearer the counterscarp than the scarp.

In the last campaign, the palisades of the redoubts thrown up near the Montagne de la Couronne, in the Pyrenees, where wood was plentiful and cost nothing, were made of trunks of trees placed close together at the foot of the escarp, and were found almost equal to a masonry revetment.

The best disposition of the ordinary palisades, in works with wide ditches, was

thought that adopted for the advanced redoubt, No. 109, at the position of Oeyras (fig. 97), where they were fixed as fraises along the counterscarp, about 2 feet below its crest, with an inclination towards the bottom of the ditch. Fraises in that situation are little likely to be injured by a front fire of cannon or howitzers, and the manual operation of cutting them away is extremely difficult, besides the men, whilst so employed, being exposed to the fire from the parapet of the work. This mode of fixing fraises was also partially applied to some salient angles, on the approach to which little fire could be brought.

It should be observed, however, that fraises, being much more liable to be broken down by vertical fire than palisades, are more adapted for field than revetted redoubts, as vertical fire can seldom be brought against the former, and it ought to form the basis of attack of the latter.

Barriers.—Each redoubt was closed with a barrier-gate, and a bridge of joists and planks.

For these four last-mentioned services more than 50,000 trees were received between the 7th July and 7th October, 1810: the greater part being firs from the Royal forests, no payment was made for them.

Abattis.—The abattis were formed solely of the stems and boughs of whole trees, well pointed, all the smaller branches being cut off, so that the front of the abattis afforded neither cover nor concealment to an assailant, although it presented a barrier of spears, five, six, and seven feet in height. The abattis were usually placed from 20 to 30 yards in front of the work, each stem and large branch being firmly staked down into the ground; and, when practicable, the trace was so disposed as to be flanked along its front by some of the defences.

Obstacles in this situation are undoubtedly the best means that can be devised for aiding the defence of works, and are seldom sufficiently attended to.

The great object of defence should be to contrive some expedient to check the assailants, and cause them to halt, if only for two or three minutes, under a close fire of musketry from the parapet. Such an advanced obstacle has ten times the effect of one of equal difficulty opposed to an assailant, when he has closed with the defenders of a work. He knows that in the latter case he has but to overcome one difficulty to obtain complete success, whereas in the former case the troops exhaust their ardour, and lose their formation on a mere preliminary effort; and every one must have felt how extremely difficult it is to revive confident boldness, and restore order for a second effort after a check.

Fir-trees were found the least, and olive-trees the best, adapted to form abattis.

Trous-de-loup.—The trous-de-loups were at first made of the ordinary dimensions and numbers, but subsequently an increased number of rows (eight or ten) of pits, only 2 feet or 2 feet 6 inches in depth, well staked at bottom and in the intervening spaces, were considered preferable, as affording no cover within them for men to fire on the work before which they might be placed, and presenting great impediments to the advance of an assailant.

During the occupation of the lines, trous-de-loups were formed in front of part of the position of Viâ Longa, consisting of a triple row of inverted cones, 9 or 10 feet in diameter at top, and of the same depth. These were found to be a most formidable obstacle, but were perhaps larger than absolutely required, as it is only necessary that trous-de-loups should be of a depth to prevent an assailant getting into them and firing over their tops, which 7 or 8 feet will effect.

Whenever practicable, from the height of the profile or the fall of the ground, the rows of trous-de-loups were concealed and protected from cannonade by forming an advanced glacis with the earth excavated from the pit.

Artillery.—The provision of artillery, ammunition, and artillery stores, was arranged by the Portuguese in the arsenal at Lisbon, on memoranda sent from time to time by the Commanding Engineer, and the guns were mounted by parties of Portuguese gunners detached from thence, as the works were prepared to receive them. It was gratifying to observe, on these occasions, by what persevering and patient labour the peasantry, with their rude means of transport, (merely the common cars of the country pushed forward by oxen,) succeeded in transporting 12-pounders into situations where wheels had never before rolled, and along the steep sides of mountains where horses would have been useless.

Although the armament of the lines ultimately amounted to nearly double the number of pieces of ordnance originally contemplated, the zeal and perseverance of the Portuguese General Rosa smoothed all difficulties, and his activity and resource seemed to render the supply of guns, ammunition, and the means of transport, inexhaustible; and, highly to his credit, every thing supplied, though rude and inconvenient, proved efficient and substantially good. The Portuguese officers and gunners employed on this duty were also zealous and active, and took extremely good care of their stores and ammunition. Their numbers assembled on the lines amounted to 3208, regulars and irregulars.

Calculation of Garrisons.—As a general rule, the garrisons of the redoubts, and the number of troops required to man the retrenchments, were at the commencement calculated on an allotment of two men per yard running of parapet for all lines; but after some time, this calculation was deemed too considerable, and the numbers were fixed at two men per yard running for all front lines, and one man per yard for all rear lines, deducting for the spaces occupied by the artillery; an addition to or deduction from these numbers being made by the Commanding Engineer in all cases where deemed expedient from local causes.

Admitting each man to require three feet to enable him to use his musket freely, this latter calculation will (whatever be the figure of the work) insure the parapet being sufficiently manned, and leave a reserve to supply the place of those killed, or in large works to charge the first of the assailants who may penetrate into the interior. It was therefore deemed preferable to the more scientific formula for allotting a man to a certain number of square feet of the interior space, which rule, though well calculated to apportion the garrison of every sized work in a similar ratio between its interior space and its length of parapet, seems too much the result of theory, which requires that each man of a garrison should have a certain space for his accommodation; whereas in practice such does not appear to be essentially necessary; for till the moment of being menaced with an attack, many of the garrison of each work will be kept on the watch on the face of the hill, and others be permitted to amuse themselves in its rear. All cooking, &c., is also performed outside of the work, so that it is only at night, or during the action which decides the fate of the position, that the garrisons are closely shut up, and then at least one-third should be kept constantly standing or sitting under arms on the banquette. Besides this, every figure from the triangle to the circle varies in the proportion the content bears to the periphery, and it is on the latter only that the defence hinges.

Scarps.—The scarps were formed by cutting the front slopes of ranges of heights near their summit as perpendicularly as the soil or rock of which they were composed could be made to stand, or on such irregularity of level as presented the greatest facility for making a perpendicular cut.

The chief difficulty in tracing a line to be scarped was to find portions of the ascent sufficiently steep, that when cut to the required angle, the base should not form a road, which might serve as a breathing and rallying point, and unless flanked, a

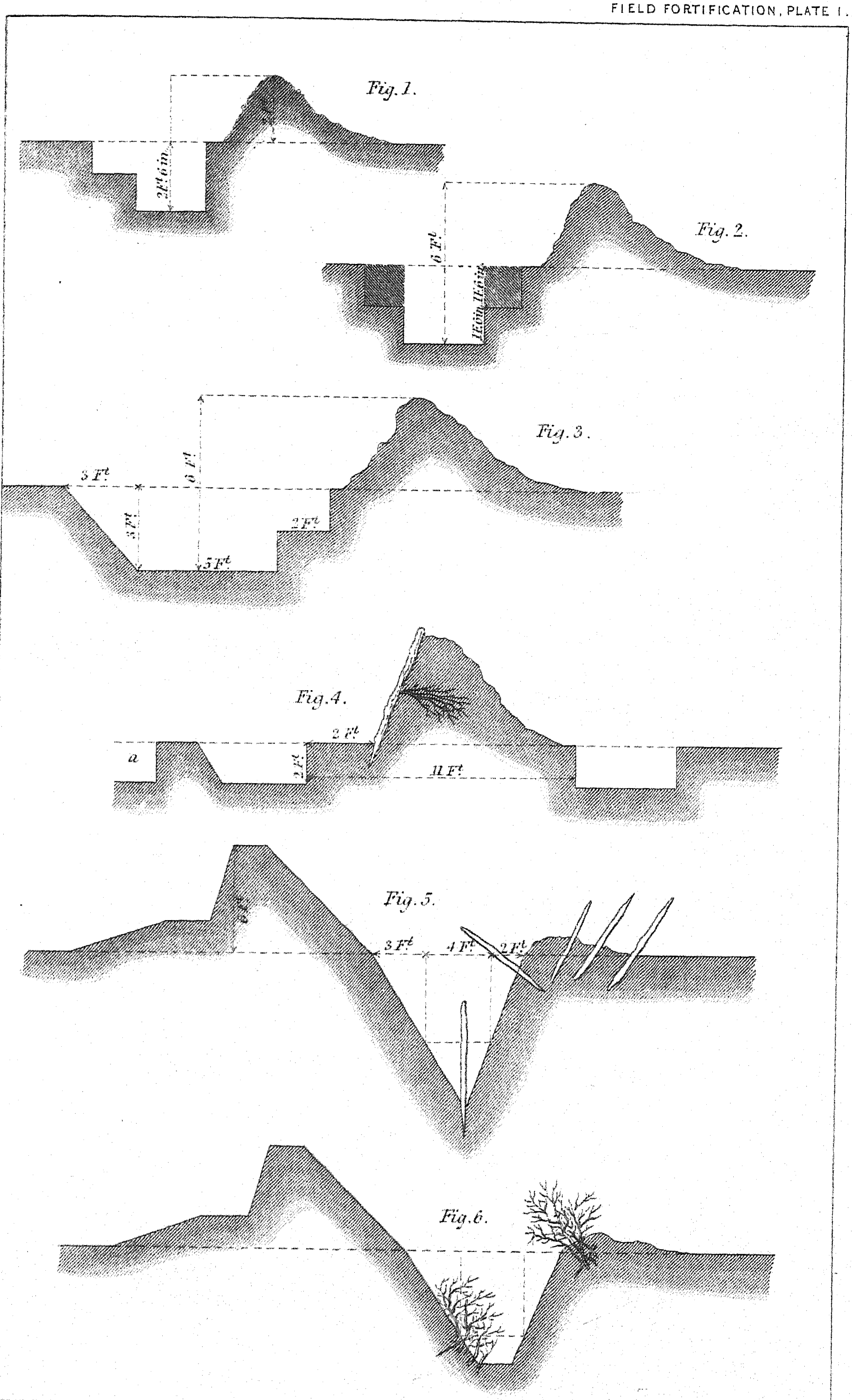


Fig. 1.
2Ft 6in.
Fig. 2.
6 Ft
Fig. 3.
3 Ft
6 Ft
3 Ft
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5 Ft
Fig. 4.
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11 Ft
Fig. 5.
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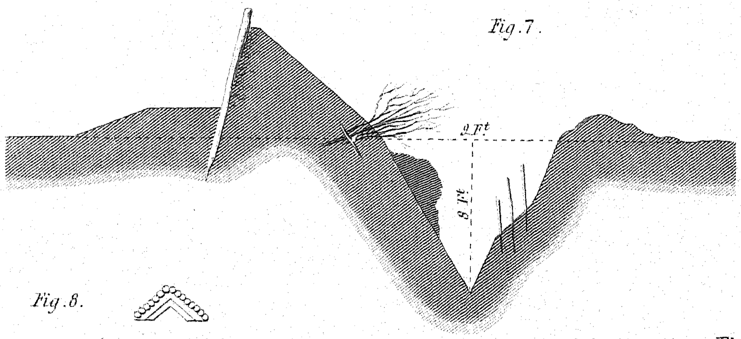
4 Ft
2 Ft
Fig. 6.

J.W. Lowry fc.



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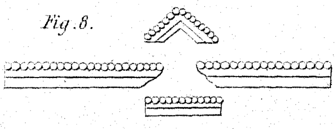

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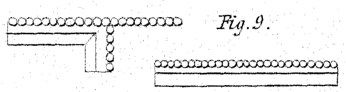

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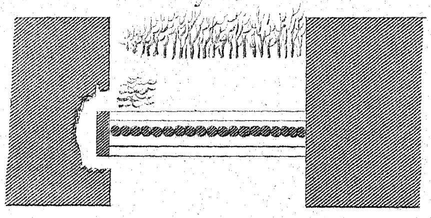

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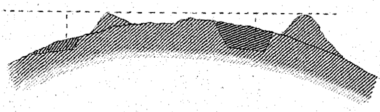

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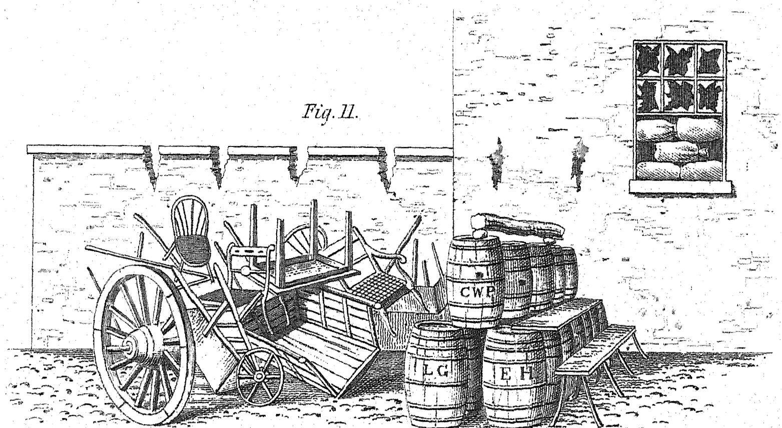

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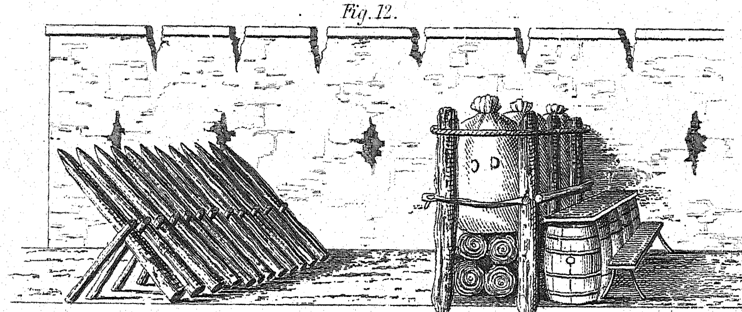


Fig. 12.

Fig. 14.

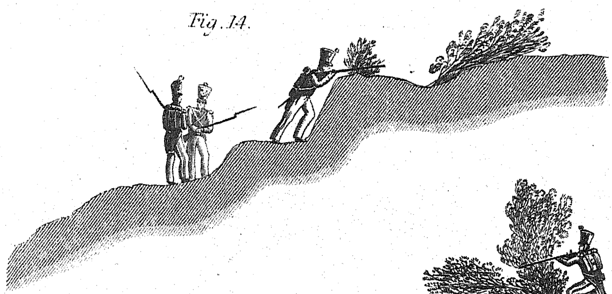
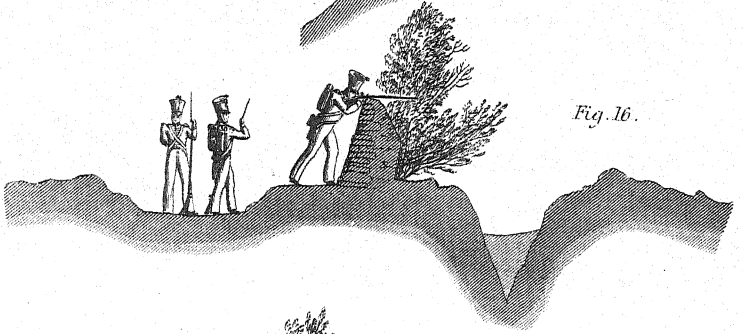


Fig. 15.

Fig. 16.



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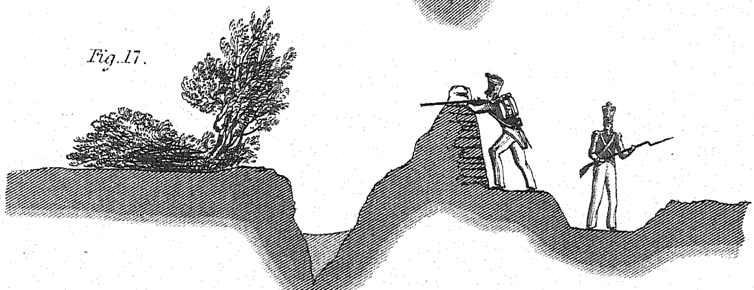

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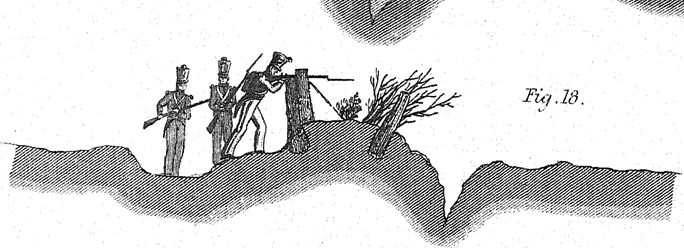

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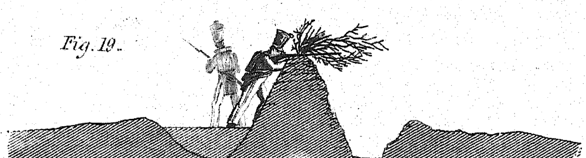

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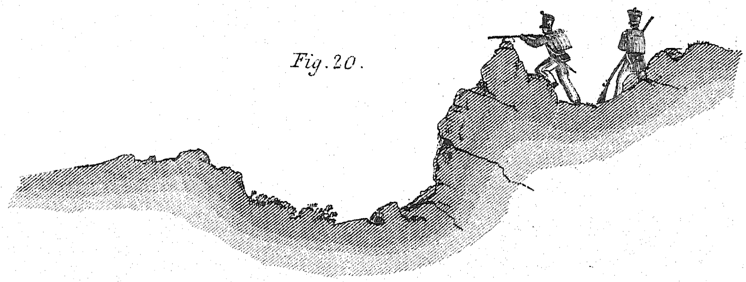

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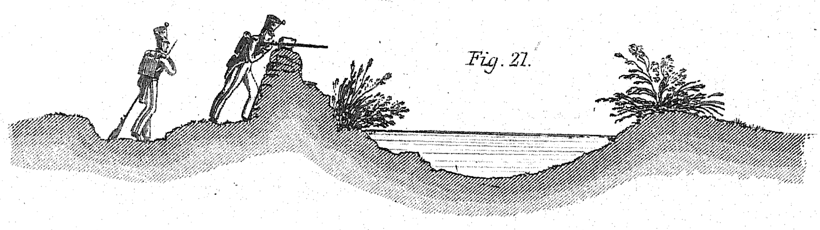

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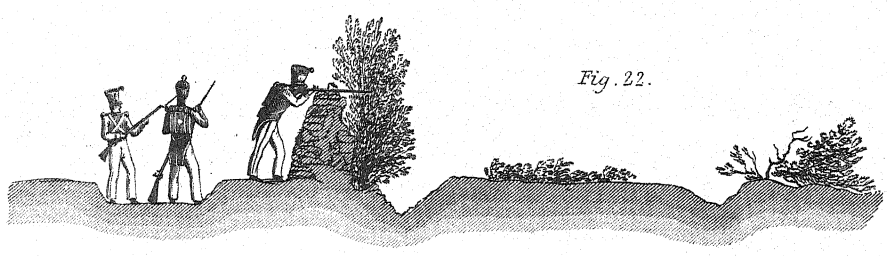

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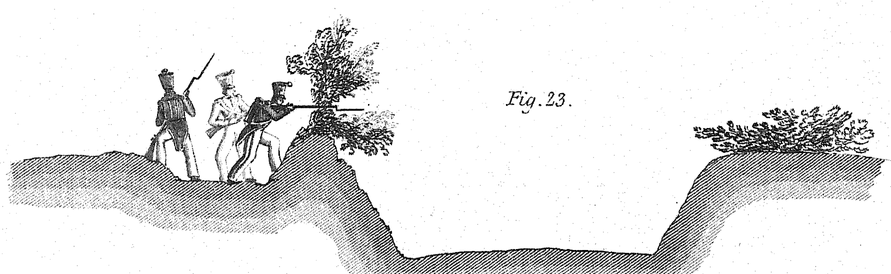

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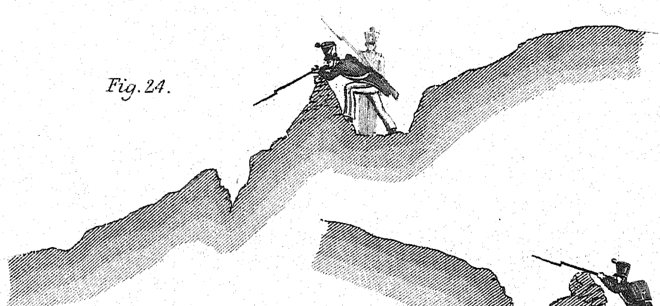

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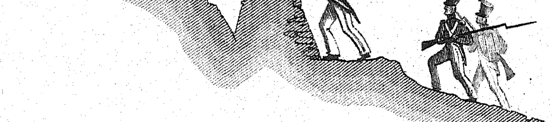

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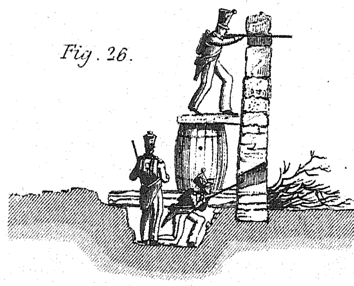

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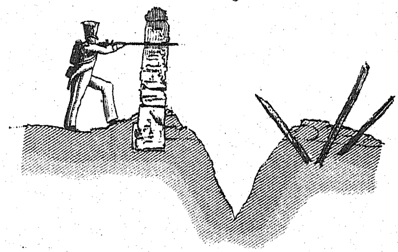

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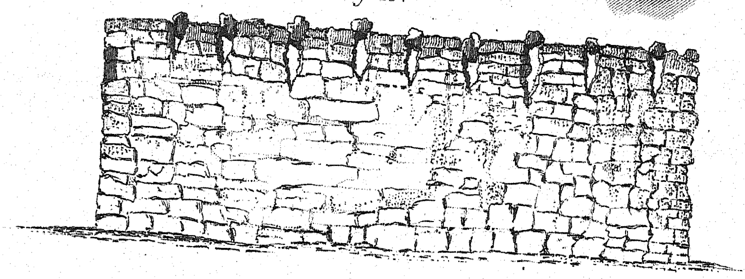

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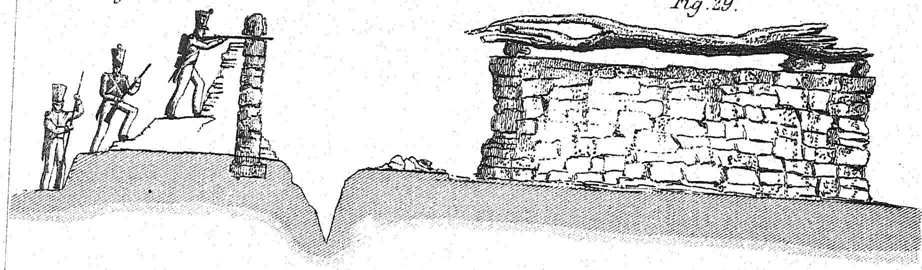

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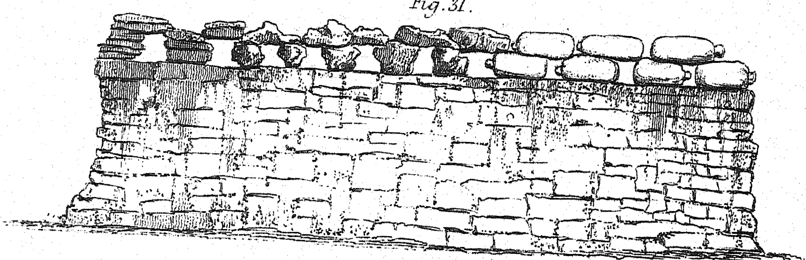
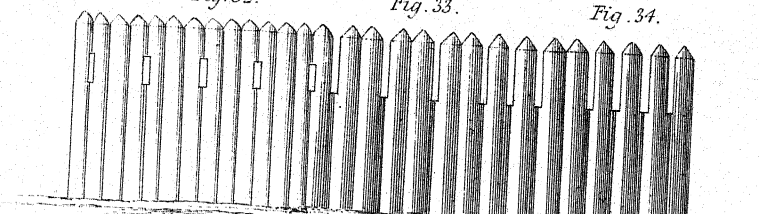


Fig. 32.

Fig. 33.

Fig. 34.



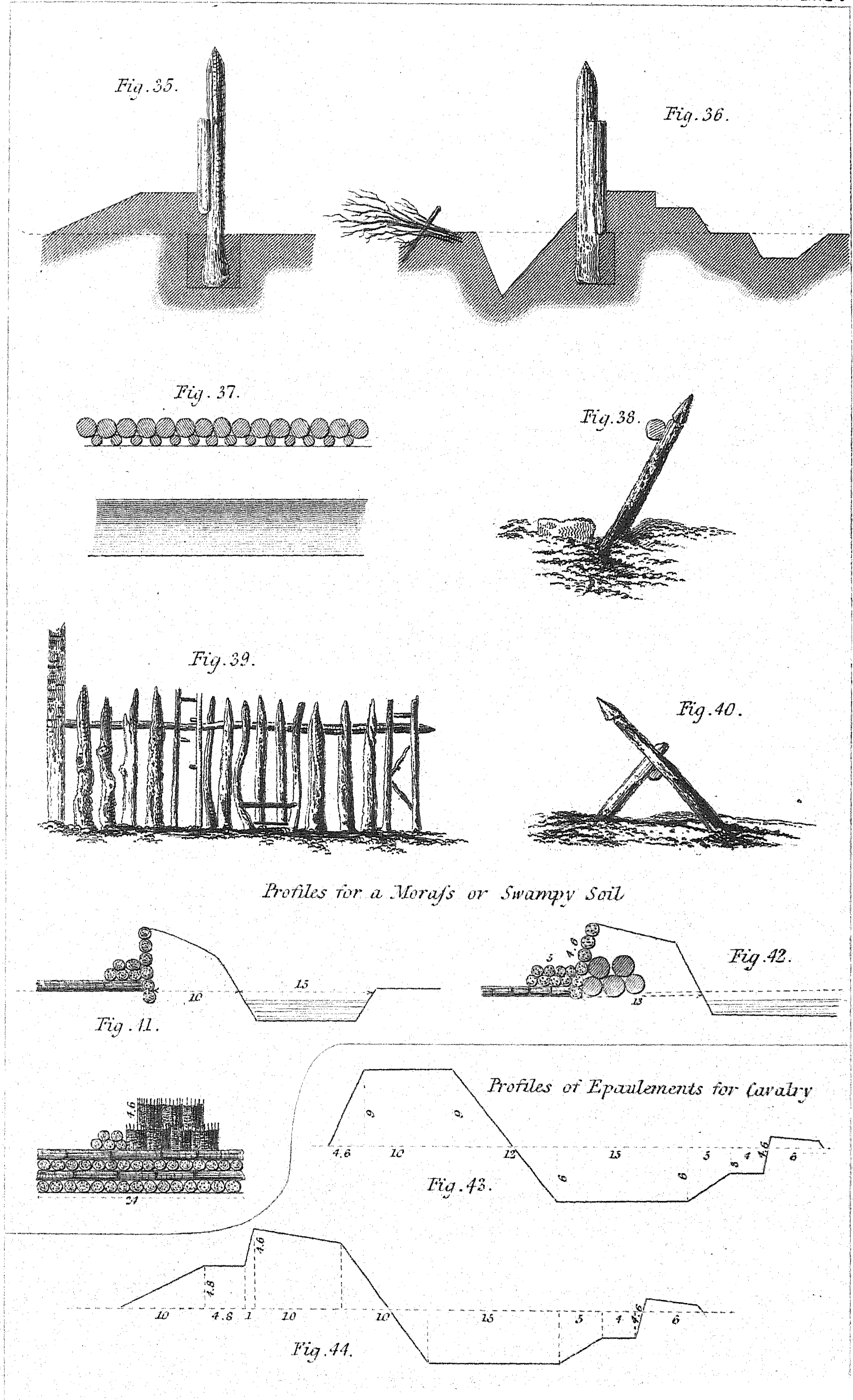


Fig. 35.
Fig. 36.
Fig. 37.
Fig. 38.
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Fig. 40.
Profiles for a Morass or Swampy Soil
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Fig. 43.
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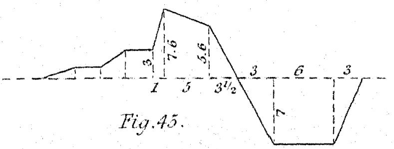
Fig. 44.

Profiles against Musketry



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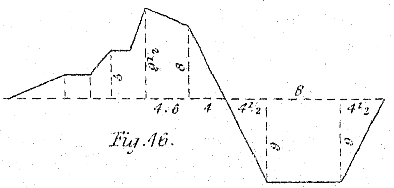

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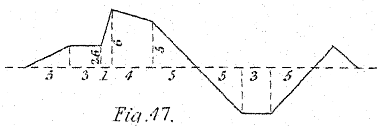

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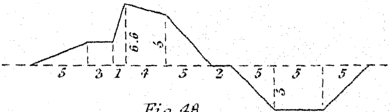
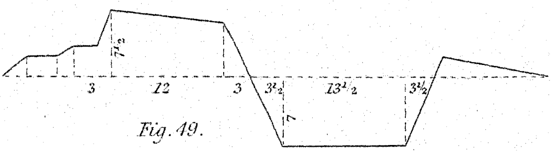


Fig. 48.

Profiles against Artillery



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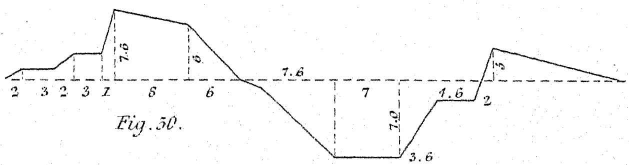

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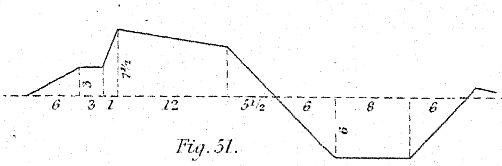

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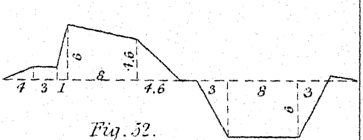


Fig. 52.

Profiles secured by Palisades

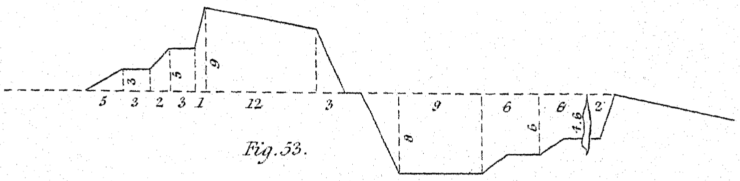


Fig. 53.

Profiles secured by Palisades

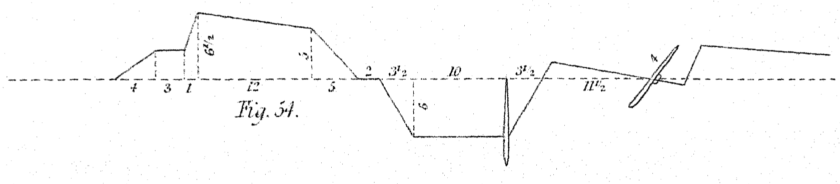


Fig. 54.

Profile secured by Chevaux de frize and Abbatis

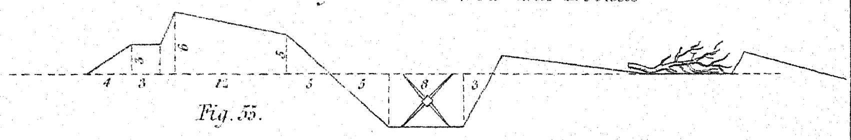


Fig. 55.

Profiles adapted to a Rocky Soil

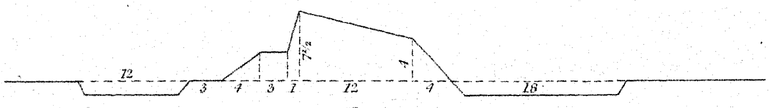


Fig. 56.

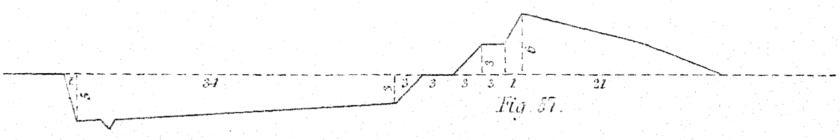
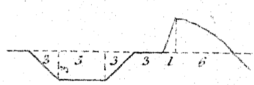


Fig. 57.

Profiles for a Morass or Swampy Soil.



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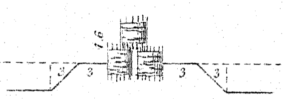

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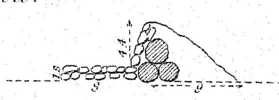


Fig. 60.

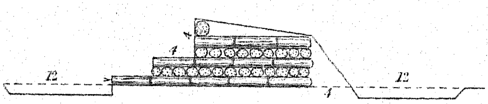


Fig. 61.

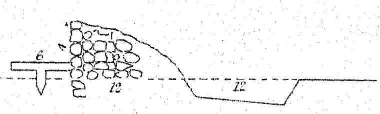


Fig. 62.

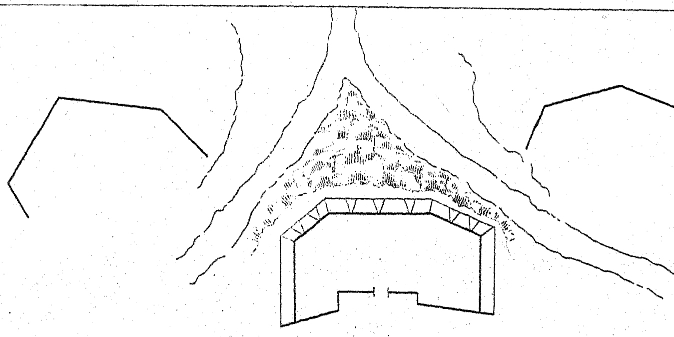


Fig. 63.

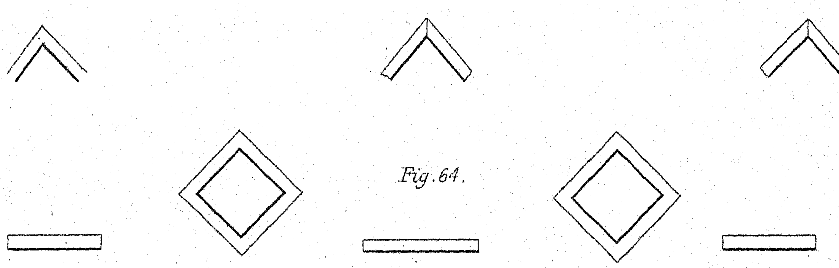


Fig. 64.

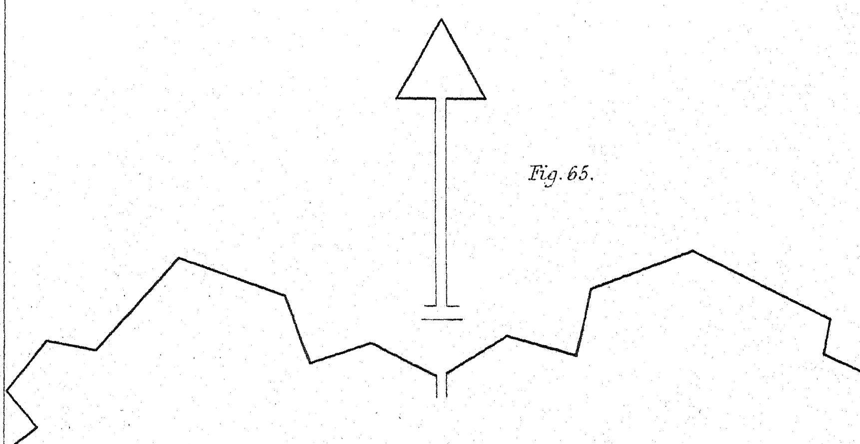


Fig. 65.

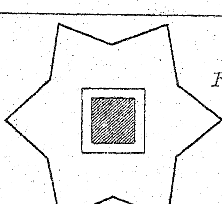


Fig. 66.

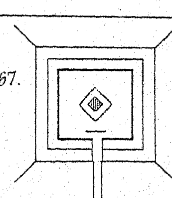


Fig. 67.

Scale 100 Yards to one Inch.

100 50 0 100

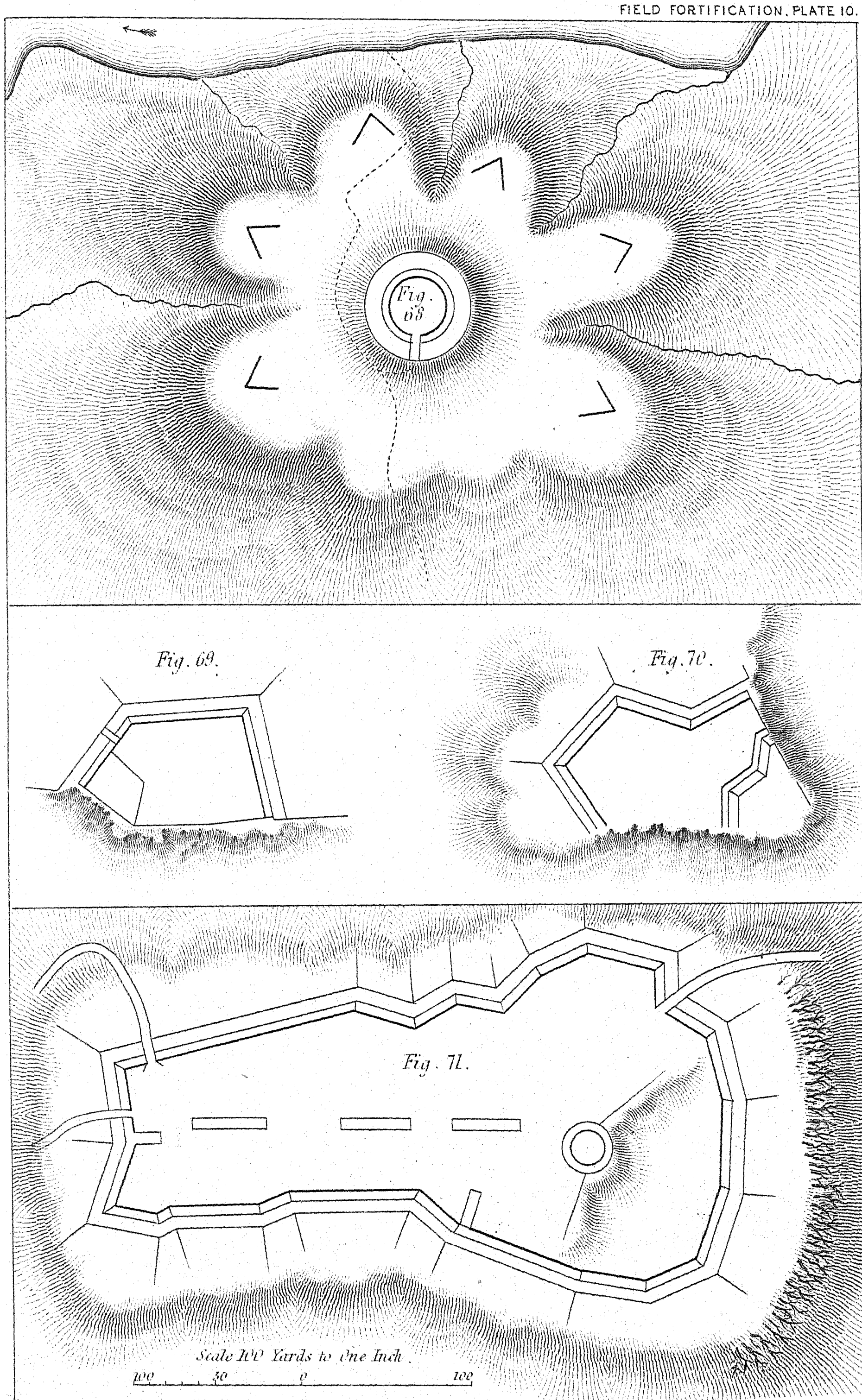


Fig. 68
Fig. 69.
Fig. 70.
Fig. 71.
Scale 100 Yards to One Inch.
100 50 0 100

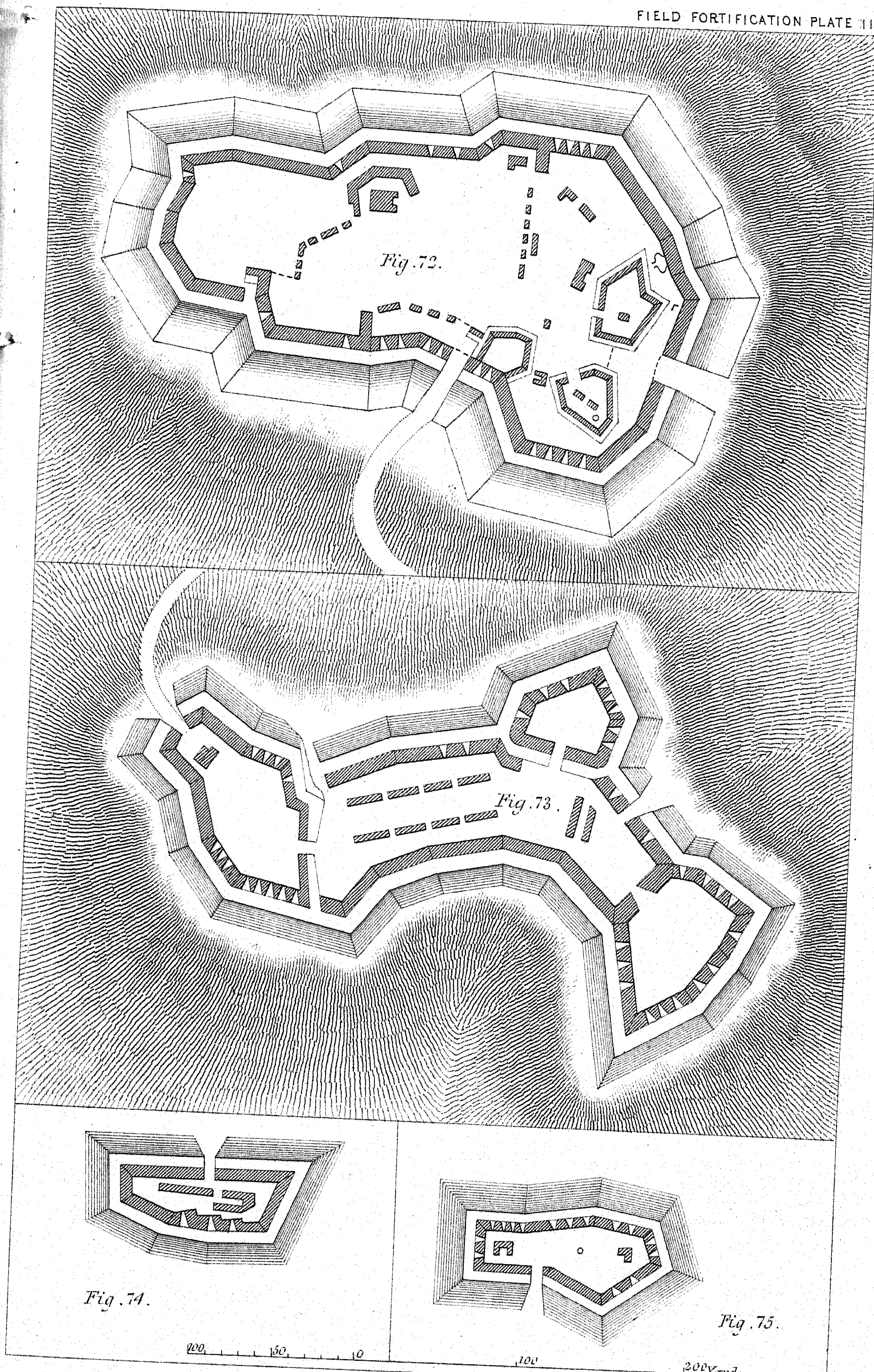


Fig. 72.
Fig. 73.
Fig. 74.
Fig. 75.
100 50 0 100 200 Yards

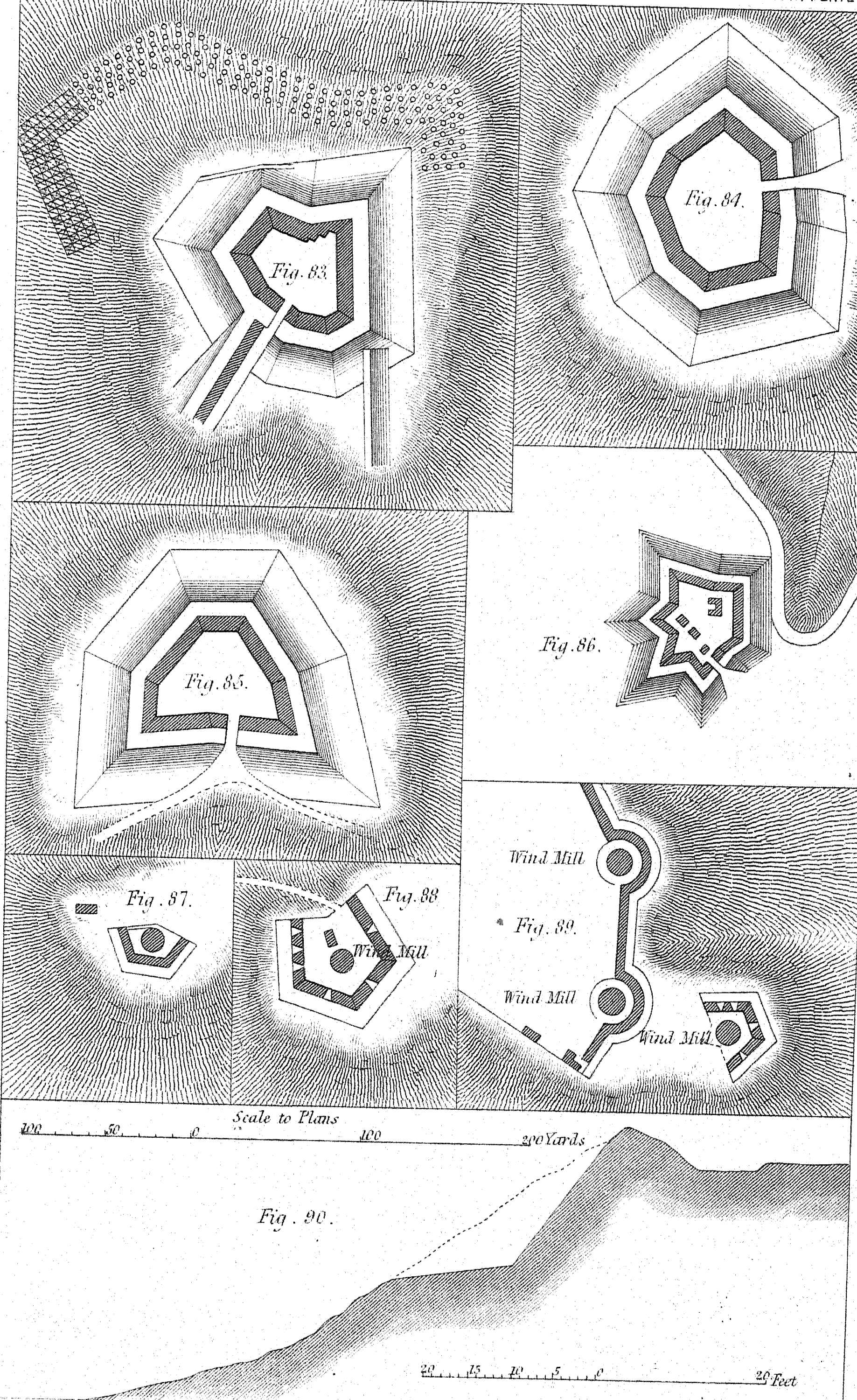


Fig. 83.
Fig. 84.
Fig. 85.
Fig. 86.
Fig. 87.
Fig. 88
Wind Mill
Wind Mill
Fig. 89.
Wind Mill
Wind Mill
Scale to Plans
100 50 0 100 200 Yards
Fig. 90.
20 15 10 5 0 20 Feet

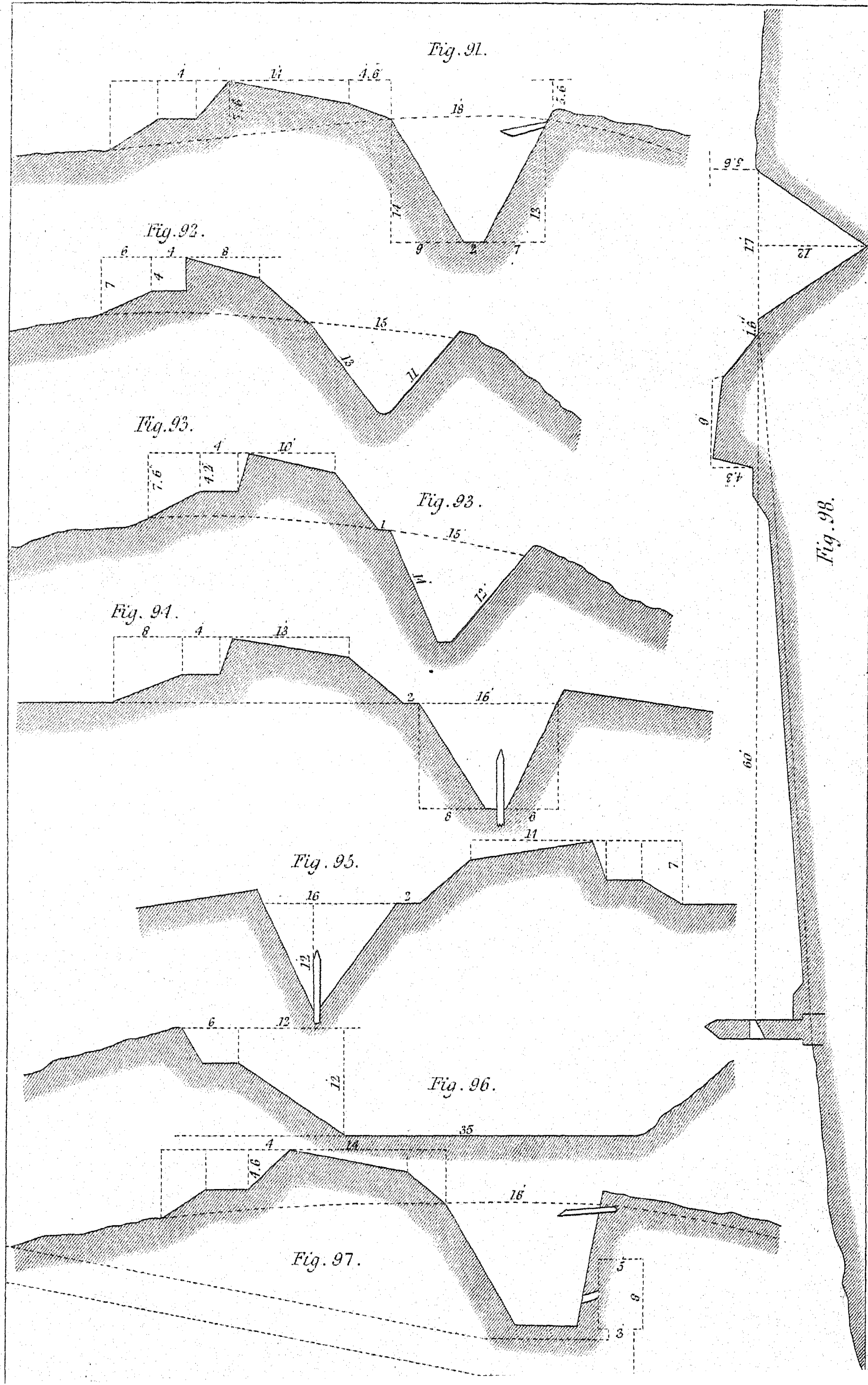


Fig. 91.
Fig. 92.
Fig. 93.
Fig. 93.
Fig. 94.
Fig. 95.
Fig. 96.
Fig. 97.
Fig. 98.

TRAVERSING PLATFORM

USED IN THE PICKET TOWERS ON THE EASTERN FRONTIER AT THE CAPE;

FOR A LIGHT BRASS 6 P^{R} OR 4 ⅖ BRASS HOWITZER, OR FOR A 5½ IRON HOWITZER, WHEN NO CRADLE IS REQUIRED.

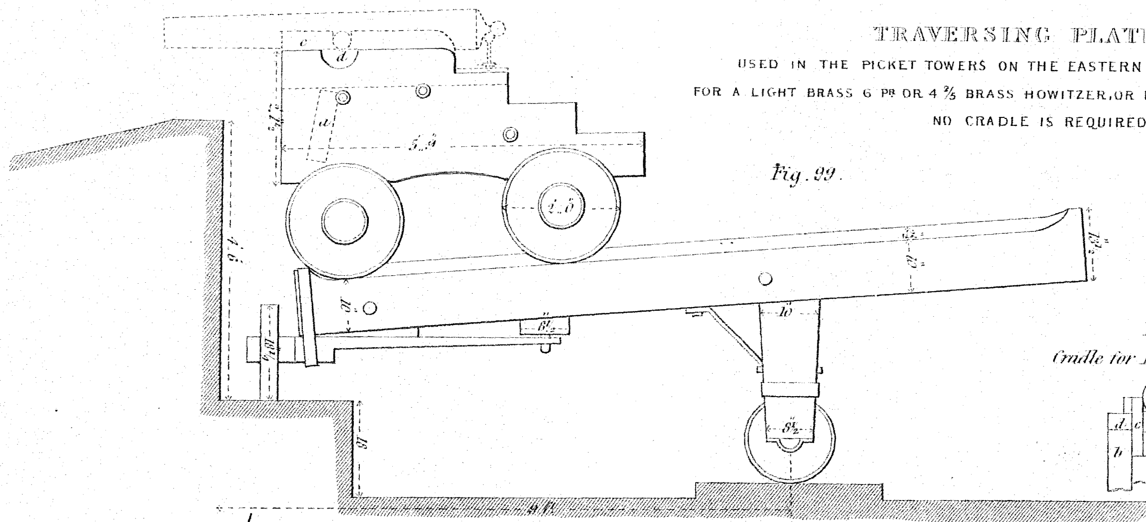


Fig. 99.

Fig. 100

Cradle for Light Ordnance

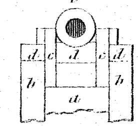
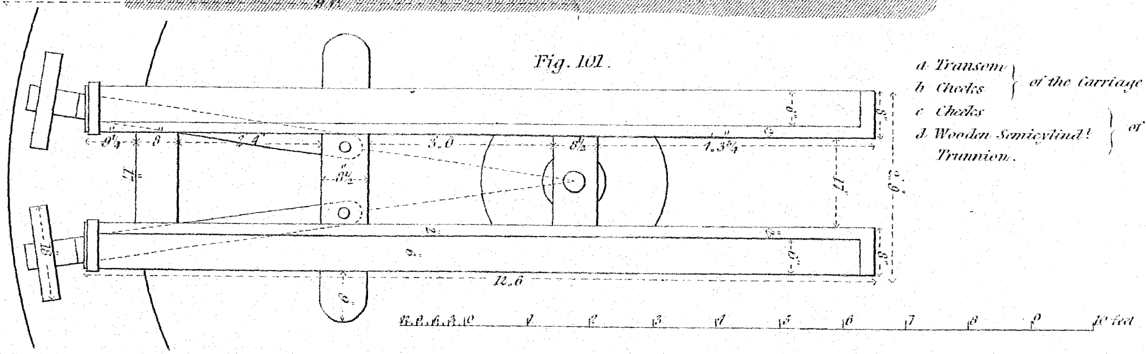


Fig. 101.



a Transom } of the Carriage
b Cheeks }
c Cheeks } of the Cradle
d Wooden Semicylind! Trunnion. }

secure communication to an assailant. Fig. No. 90 is a section of a scarp of nearly two miles in length, formed along the summit of the front of the position of Alhandra, in August and September, 1810. Much of the upper 20 or 30 feet of that range of heights was found to be a ledge of precipitous rock only covered with a few feet of earth; which covering being removed and thrown down the face of the hill, the rock behind it was readily made insurmountable to infantry by means of blasting. At other points a species of sandstone, which, when cut through, stood nearly perpendicular, afforded great facility to the formation of the scarps; indeed, without some natural aid, scarping will seldom be found practicable.

It never was presumed that scarps could be trusted to without defenders; but it was considered a great point gained to have rendered portions of ground of such difficult access as to be safely left to the guard of a small corps, or to unsteady troops, such as the militia and ordenanza on the lines. For the purpose of better watching, and to insure the ready approach of troops and field artillery to all points of the front scarped, a line of interior road was formed nearly parallel to the scarps of Alhandra and Picanceira, at the shortest convenient distance from the front.

Roads and Communications.—The military roads generally were traced along the rear of ranges of heights on the shortest line, concealed from the view of the ground in front; they were perfected during 1811, so as to form a ready communication along the front line from the sea to the Tagus, with direct communications from the rear line.

Several miles of the lateral road were entirely new, as also most of the direct communications from the lateral road to the works; but the intermediate communications between the advanced works and rear line were merely the original car roads of the country, widened and rendered practicable for military purposes. Many of the communications along the valleys were of necessity paved to keep them in a state to be used; but generally the heights over which the main communication passed were rocky or abounded with loose stones and other materials which readily formed into firm roads. Fig. 96 is a section of the covered road commenced at Almada, and intended to be carried from the right to the left of that position.

Telegraphs.—The telegraphs were composed of a mast and yard, from which latter balls were suspended; the vocabulary used was that of the Navy, many sentences and short expressions peculiar to the land service being added. These telegraphs readily communicated with each other, at the distance of seven and eight miles; but in consequence of the ranges of hills interrupting the view, it required five principal stations to communicate along the front line, viz. at Alhandra, Monte Agraça, N. S. de Socorra, Torres Vedras, and Redoubt No. 30, in rear of Ponte de Rol.

FORT, PERMANENT.*

The name of 'Fort' has been used as a general term for works of very different character, capacity, construction, and object,—optionally applied to bastioned polygons, and to unenclosed sea batteries destitute of the means of self-defence. To arrive, however, at some definite view of construction, it may be proper to consider forts as essentially works of a defensive character for some specific object; not forming part of a system of collateral lines of defence; but, generally, for the occupation or command of some particular pass, entrance of a harbour or river, or some important point on a line of land or water communication,—requiring only a small garrison, never

* By Major-General Fanshawe, C.B., R.E.

intended to deploy; therefore, with small developement, thoroughly flanked by its own construction, or by auxiliary expedients, such as caponières, reverse fires, &c.,—having its escarp well covered if possible, its ditch deep and narrow, its approaches limited and well seen, and its barriers secure. Works of this nature are generally of a permanent construction; and for field-works, or enclosed portions of a collateral system of lines of defence, the term Redoubt appears more applicable.

The precise nature of the site of the fort will vary; and natural impediments, such as a precipice, swamp, or water, render it possible, nay advantageous, to dispense with artificial constructions and formations, which, for a garrison intended to deploy (as from an intrenched camp or a fortress), would be available for their tactical operations.

Thus, a continuous covert-way and outworks appear unsuited to a fort. An escarped precipice, or an inundation, rendering great part of its contour unapproachable by an enemy, is to be preferred to the formation of a glacis, on which, with a large garrison of a fortress, his approaches would be contested.

Whenever the curtain would be so short that its ditch cannot be thoroughly seen from the rampart, the bastioned system is inapplicable, because, unless there be lower casemated flanks, the escarp would either be too low, or the ditch would not be seen; one-twelfth or one-tenth of the length of curtain being the greatest height of escarp that the collateral defence of the bastioned system admits.

For shorter lines, caponières or reverse fires should be resorted to.

Dead angles, if unavoidable, may be advantageously casemated for musketry loopholes, or for howitzer fire, provided the ditch be sunk immediately in front of the casemates, into what is technically called 'a drop,' which should be from 12 to 15 feet wide.

Although external works are not suitable to forts, it will generally be desirable that the bridge or entrance be covered by a place of arms or tambour, whose faces should be seen from the rampart, and be countermined.

The mechanism of the draw-bridge will depend in some measure upon the position and construction of the gateway.

It is desirable that the accommodation for troops and stores be casemated: this may frequently be accomplished, with sufficient means of ventilation, under the terreplein of the rampart; and if the 'pente' of the dos d'ânes can be so arranged as to carry off the water, and the covering above it be sufficient, the arches may be connected by a series of groins, so as to obtain the greatest possible internal capacity for the casemates.

A portion of the work should be retrenched or cut off, or an isolated building constructed in the interior as a Réduit de Sûreté, commanding the entrance, and the most assailable points.

The proportions and mode of obtaining secure foundations, and of constructing the revetments, magazines, casemates, tanks, sluices, draw-bridges, &c., are given under the different heads.

The figure of the work, and its defilement and relief, will depend upon the locality and the immediate object of the work, and will guide the Engineer in the application of the above general observations; and his own judgment will naturally lead him to artificial constructions inversely as natural impediments are wanting, or circumstances call for especial caution; so as much as possible to obtain uniformity of strength in the simplest manner, and to apportion the defences and means of resistance in all parts of the fort to the object of its occupation.

FORT, FIELD.*

For the defence of important military points, either entirely independent of other works or in advance of a fortress to delay the enemy in attacking it, small enclosed works for garrisons of from two hundred to five hundred men are often required to be constructed.

If large, they are often constructed with bastions or half-bastions, but these must necessarily be so small and close together as to give a very indifferent flanking defence to the ditch: star-forts also are badly flanked, therefore wooden caponières at the angles or at the centre of each side of the work, or else galleries in the flanks of bastions at the level of the ditch, should be constructed (*vide* 'Caponière') as shewn in Plate I.

The garrisons, artillery, and ammunition in these forts being much exposed to the effect of shells, should be protected by bomb-proofs, which may be arranged as in the Wolfsberg or Gneisenau Fort, erected in front of Colberg by the Prussians in 1807, which delayed the attack of the town forty-four days; but the roofs must be much stronger, and Plate I. shews a proposed modification of that work, with secure bomb-proofs, and provided with a stockade defended by a blockhouse as a keep at the gorge, which would be better than an earthen parapet, if that side is not liable to be battered, or if the work is in connection with others, as less cover would thus be afforded after it is taken.

If merely a small work for fifty to a hundred men ~~on~~ or a keep to a larger work is required, a bomb-proof barrack, similar to those shewn in Plate II. figs. 1 and 2, protected by a parapet and ditch, and provided with embrasures for artillery and musketry, might be adopted.

That shewn in fig. 1 is made proof against field artillery; its roof is formed of beams supported by strong posts, and covered with fascines and earth, with tarpaulins to keep out the wet; and it has a parapet on the top formed of fascines or earth to protect a sentry against riflemen; the access to this is by a stair in the entrance caponière, which flanks the gorge ditch: the other ditches are flanked also by two caponières.

That shewn in fig. 2 is only proof against musketry, but is covered with earth as a security against fire; its form secures a complete flank defence; but if a very small building only is required, the next best form, viz. that of a cross, might be substituted.

Ordinary buildings of brick or stone might likewise be adapted to the same purpose, the roofs being strengthened and covered with earth, and the walls likewise protected by throwing up parapets in front.

Defence.—The gun blindage described in vol. i. p. 159 is intended only to be placed where it is not exposed to direct fire, and has been seldom used except in such positions; but experiments (on the Continent) have proved, that by laying a ~~circle~~ tier of beams 12″ × 8″ across a portion of the embrasure, and covering them with 4 feet of earth, a protection is thus formed in front of the roof of the blindage, which enables it to resist a great deal of direct fire, and renders it much more secure against shells.

FORTRESS, PERMANENT.†

Marshal Marmont defines fortresses as those of dépôt, and for strategetical purposes, to which may be added maritime fortresses. Guibert, who held the métier of

* By Captain Bainbrigge, R.E.

† From the Corps Papers, vol. ix.

an Engineer very cheap, induced the Emperor of Germany, by his writings, to dismantle all the fortresses in Austrian Flanders; but time has effected those *revolutions* in most Governments, those changes in the organization of armies, in tactical operations, and the use of immense trains of artillery, and the conversion of every town into a fortified place, of which, in his 'Essai Générale de Tactique,' he exhibited the folly. Fortification as a science and art is now applied in the manner contemplated by that talented author,—that fortresses should be large and few in number, and their destiny regulated by battles,—that they should be considered accessories and not principals in war; for if they are small, they are neither rallying points nor points d'appui, nor serve as dépôts to receive succours; they are easily taken or masked, and left behind without inconvenience, for it is rare to see a small garrison turning the defensive into the offensive; whereas large fortresses can receive the débris of a beaten army, become the entrepôt of provisions and stores, and are capable of containing a sufficient force to resume the offensive when opportunities occur.

Lloyd in his 'German War' observes, that "most men think a fortress or camp is well placed if they cannot be approached without great difficulty, which is true only in case they have in themselves all the resources necessary for their defence; but as this seldom or ever happens, the perfection of the one and the other would be, to find a situation that presents to the enemy all the difficulties possible, which at the same time may be easily succoured if necessary."

The functions of fortresses are likewise, that they cover a country, and thus subject an enemy to the necessity of attacking them before he can penetrate further. These things being considered * with others already adverted to, the position of a fortress will be found advantageous by being placed at the junction of two rivers, because in such situations the enemy will be obliged to divide his army into three distinct bodies before he can be able to invest it, one of which may be repulsed and discomfited before the others can succour them. Thus two sides of the fortress remain open until the blockade is completed, which cannot be done in a single day; neither can the necessary communications between the divisions of the enemy be kept up without the use of *three* bridges, which will be exposed to the hazards of the sudden storms and inundations which happen in the campaign season.

Recurring to the principle of defining fortresses for the defence, as

1. Maritime places,

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* "Il est question maintenant, de considérer la défense de l'ensemble du pays, du corps de l'état, de tout enfin, pour l'intérêt et le salut du quel la fortification de ses diverses parties a été ou du être ordonnée. C'est ici l'objet de la fortification, vu en grand, et son utilité envisagée relativement à la stabilité des empires, à la securité des gouvernemens, et à la protection qu'ils doivent aux peuples contre la guerre et ses ravages; et si les livres qui précédent, ou peut-être considérés, les uns comme la fortification de l'officier en général, les autres comme celle de l'ingénieur ou du commandant de place en particulier; celui-ci, s'il remplissoit bien son titre, pourroit être à bon droit, regardé comme la fortification du général d'armée, du ministre d'état, du prince, roi ou chef de l'état, de quelque nom on veuille l'appeler. . . . .

"Par défendre les états par la fortification, je n'entends point uniquement les hérisser sur chaque avenue ou partie accessible des frontières, du places fortes qui vous forcent à faire un siége à chaque pas que vous y ferez. J'entends une combinaison des moyens de l'art avec les moyens défensifs de la nature, telle que ceux-ci deviennent insurmontables, tant que ceux-la n'auront point succombé: j'entends par les moyens d'art, non seulement les places fortes, mais encore les camps retranchés et positions fortifiées, les camps retranchés sous les places, ceux alongés en lignes pour couvrir un pays, les abattis, les inondations, canaux, routes et communications militaires, enfin les postes retranchés; en un mot, tout produit d'art, qui concourant avec les obstacles naturels, compose avec eux un ensemble capable de donner aux défenseurs d'un état, toutes sortes d'avantages sur ceux qui l'attaquent."—*Bousmard*, livre v.

2. For the security of dépôts,
3. As strategetical points,

it is proposed to consider the method by which each should be fortified, without reference to any especial system.

1. *Maritime Fortresses.*—It is conceived that a simple enceinte, comprising only a rampart, ditch, and covert-way, is ample protection to a maritime place, with a chain of detached forts in advance, so as to protect the docks and stores from bombardment: the number of forts necessary must depend upon localities; those in front of the enclosures at Lyons and Paris are good specimens of detached works.* The enceinte enclosing the naval arsenal may be constructed upon any system best adapted to the ground without outworks, but unassailable by escalade; and it is not deemed necessary to have a large quantity of bomb-proof cover, or more than is sufficient to secure the combustible stores.

2. *Fortresses for the security of dépôts* of arms, ammunition, and for the manufacture of warlike stores, should be constructed with the due care and skill that money can provide for, with adequate bomb-proof cover, in proportion to the size of the fortress, as explained in 'Defence of Fortresses:' the fronts of fortification (whatever system may be adopted) to be countermined, if the ground will permit.

3. *Strategetical Fortresses,* for the support of an army in the field.—The value must depend principally upon the locality, which it is not possible to explain without reference to particular territories, except that already adverted to at the confluence of rivers; but Lyons, Strasburg, Mayence, and Luxembourg are strategetical points of importance. This description of fortress can only be applied to large possessions; as regards the British empire—such as the Canadas, British India, England, and Ireland.

G. G. L.

FORTRESSES, FIELD, OR PLACES DU MOMENT.†

" *Places du moment*, qui pour être construites en terre, dans le courant d'une campagne, n'en sont pas moins réellement des places de guerre."—*Essai Général de Fortification*, livre v. chap. ix.

The judicious emplacement and construction of *places du moment* must be of interest in our Service, as there are so few fortified places in the British dominions. Yet they have all the properties and consequences of fortresses, of which they may be deemed those of the least value. But if we go back to the Peninsular War, subsequent to the publication of the 'Essai Général,' we shall find that the *place du moment*, or *field fortress*, was of great importance; for example, Saragossa, constructed by the Spaniards,—Burgos and Salamanca, by the French,—and Abrantes and Peniche, by the English. Bousmard considers these works under the term of intrenched posts, executed with sufficient care to prevent a coup de main, and to oblige an enemy to go through all the preliminaries, and frequently the whole process, of a regular siege,—in reality, fortresses.

Works of this nature should only be undertaken when there is ample time to execute them with care and solidity, and when local circumstances favour their construction. Among the latter advantages, an old town wall,‡ large substantial build-

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* See Forts, Detached. † From the Corps Papers, vol. ix.

‡ "Ce sont ces places du moment, si je peux m'exprimer ainsi, qui ont soutenu les siéges les plus vigoreux, c'est qu'un commandant qui fait réparer une mauvaise enceinte imaginer les obstacles, les faire naître, les avancer, pour ainsi dire, sur les pas de l'assiégeant."—*Guibert*, '*Essai Général de Tactique*,' second part, chap. xvi.

ings whose walls cannot be destroyed by field artillery, and which can be well secured by blindages,—inundations, escarpments, and abattis, serve as excellent accessories in front, to be connected by substantial redoubts, protected by block-houses and fougasses.

To render this description of fortress of value, it must be well armed, with at least 12-pounders and 6-inch howitzers and mortars: light traversing platforms should be placed in the salients, and ground platforms in the flanks; expense magazines provided for, with a sufficient supply of water, provisions, and stores.

Places du moment ought to be of sufficient extent to require at least 1800 men, or they become mere field-posts; they are applicable to defensive and offensive operations, where it is obvious what site to choose and what importance it is desirable to give to the works in relation to the object, the number of troops, and provisionment to spare. Regular fortresses are constructed at a vast expense, and the position not always applicable to the circumstances of the moment.

G. G. L.

FORTS, DETACHED—Usually placed in front of maritime fortresses, to secure the arsenal from bombardment at a distance of from 3000 to 4000 yards: they should be secure against a coup de main, and constructed so as to resist a regular siege, and sufficiently near each other to obtain from artillery a cross as well as a collateral fire. *Detached Forts* should also be placed at the principal points which command the anchorages, to prevent a bombardment from the sea; and the body of the place, or *enceinte*, in rear of them, may be either a simple loopholed wall, à la Carnot, or rampart, ditch, and covert-way, with or without outworks, according to the importance of the fortress and the means of relieving it.

Detached Forts have lately been placed from 800 to 1200 yards in front of strategetical fortresses, as at Paris, Lyons, Mayence, and Cologne.

In the description of the *German System of Fortification*, by General Brèze, a minute detail is given of the advantages of this mode of fortifying places, as explained in Plates I. and III.: in all cases detached forts should be flanked all round.

The figures in the Plate of Detached Forts explain the French system, as adopted at Paris and Lyons.

Fig. 1 represents some connecting forts around the village of St. Denis, which protect each other by a collateral fire; the intermediate ground to be inundated. Their fronts vary from 328 to 527 yards, and they are in advance of the *enceinte continue* about 1100 yards.

Fig. 2 forms part of a range of forts to cover Lyons on the left bank of the Rhone, which are constructed in low ground. *Fort des Breteaux* has three fronts of 284 yards, with a gorge of 437 yards: the latter contains the barrack and magazine. The interior redoubt is quadrilateral, with escarpes detaché, with loopholes and machicoulis (see Plate VII. of the Bastion system), and the terreplein of the fort forms the ditch of the redoubt.

Lunette des Charpennes is revetted and casemated throughout and loopholed, with a dry ditch and glacis, and an advanced wet ditch. This work sees the reverse of the Forts des Breteaux and Tête d'Or, which constitutes the peculiar nature of this lunette.

Fort de la Tête d'Or is a kind of bonnet de prêtre, with very obtuse angles, flanked by bastionets* (see Plate VII. of the Bastion system). This fort is revetted by a de-

* A caponière at the salient angle instead of the re-entering, as adopted in the German system.

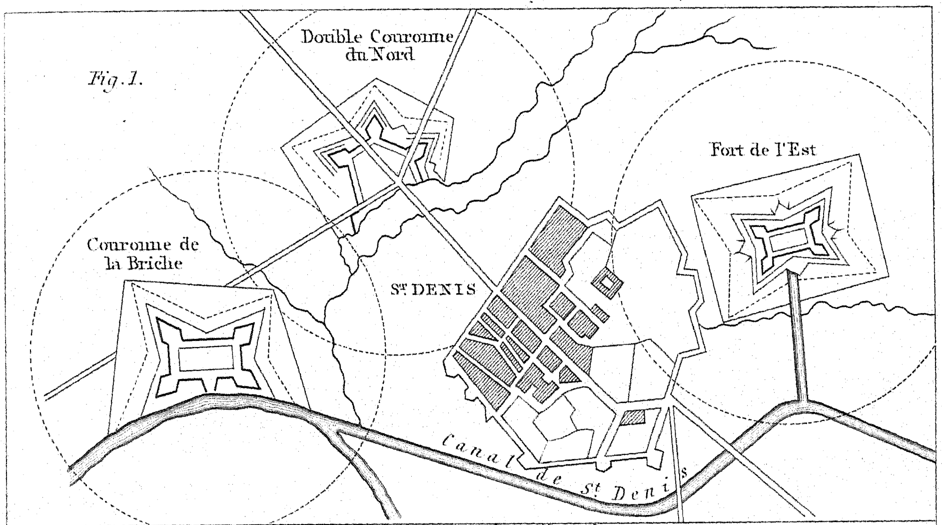
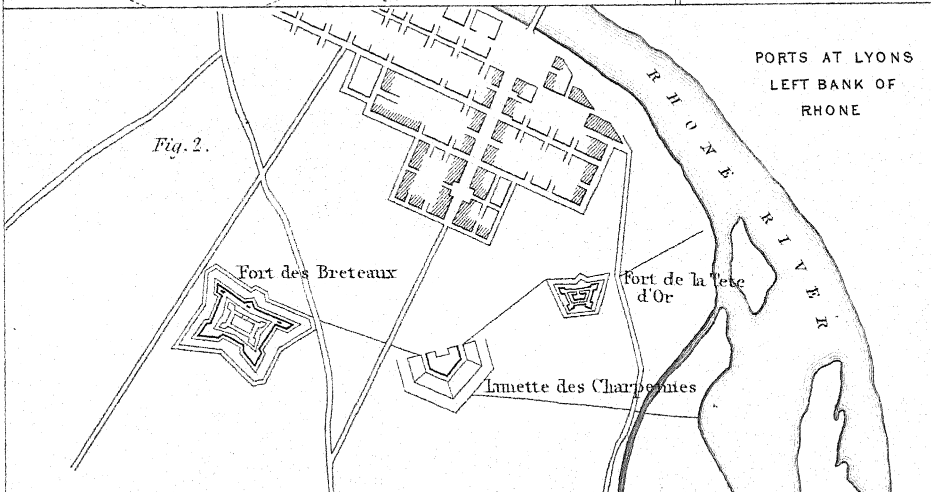
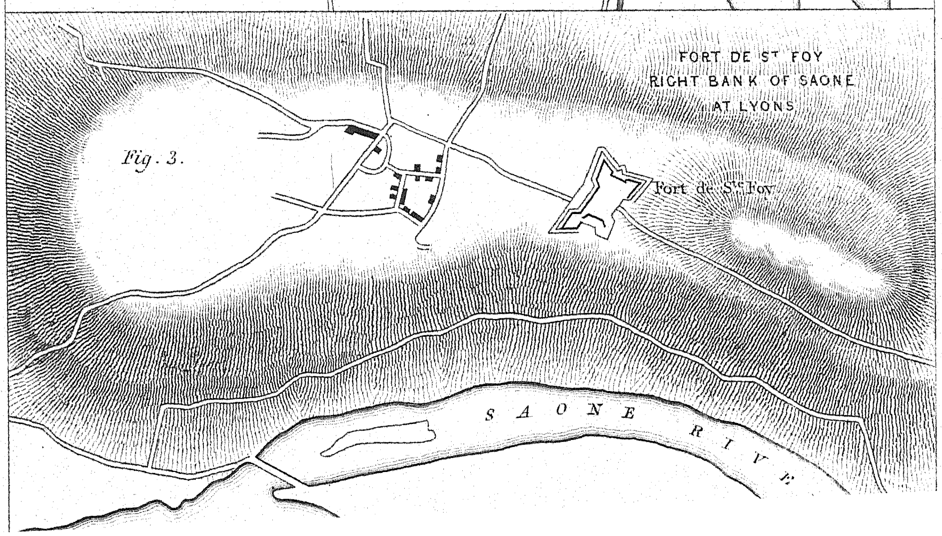


Fig. 1.
Double Couronne du Nord
Fort de l'Est
Couronne de la Briche
St DENIS
Canal de St Denis


PORTS AT LYONS
LEFT BANK OF
RHONE
Fig. 2.
RHONE RIVER
Fort des Breteaux
Fort de la Tete d'Or
Lunette des Charpennes


FORT DE ST FOY
RIGHT BANK OF SAONE
AT LYONS
Fig. 3.
Fort de Ste Foy
SAONE RIVE

tached escarp with a chemin des rondes; and the middle of the gorge is occupied by a defensible barrack, which is bomb-proof and loopholed.

Fig. 3.—*Fort de Sainte Foy* is a quadrilateral of which two sides are bastioned fronts from 219 to 361 yards in length: the escarps and counterscarps are revetted, and the parapets of the bastions have batteries à l'Haxo, as explained in Plates VI. and VII. of the Bastion system. This fort is built upon elevated ground.

One observation is necessary in conclusion, which appears to be omitted by most of the advocates of fortifying with detached works, however applicable they may be to circumstances,—that they want the homogeneous character of a fortress; and it is conceived that eight detached forts can never be equal to an octagon of a similar construction.

The division of the force, resources, and responsibilities, all tend to weaken the value of detached forts, except in advance of a fortress of some strength.

Advanced Forts, placed beyond the covert-way within musketry fire, must be considered distinct from those called detached, such as lunettes à la Darçon, and other works open at the gorge: they should however, if possible, be countermined, and secure from a coup de main.

G. G. L.

PERMANENT FORTIFICATION.

In order to give a clear view of the systems of fortification constructed in the present day, or rather upon which the constructions of the present day are founded, it has been conceived desirable to explain them from the works of those countries from which the systems have emanated, as far as practicable. They will consist, in conformity to this arrangement, of

1. The System of Coehorn.
2. The French or Bastion System.
3. Montalembert's System.
4. Carnot's System.
5. The Prussian or German System; with
6. A comparative Value of these Systems.

COEHORN'S SYSTEM.*

SECTION I.

Coehorn was an Engineer of Dutch extraction, justly celebrated both for his abilities and the services which he rendered to his country, his zeal for which caused him to make the knowledge of the "Attack and Defence of Places" so much his study, at the time when they were of the utmost importance to it, that he even increased their utility. Opposed to Vauban in many instances, and especially at the siege of Namur, in the year 1692, he obtained on this occasion the praises which talent, too great to feel the impulse of envy, never denies to merit. No doubt jealous of his rival's discoveries in the effects of ricochet fire, and its use in the attack, Coehorn invented a small mortar for throwing shells, which up to this day is named after him. This mortar is so light that it might be served and even carried by one man, and brought into play at a moment's notice on any occasion; and only requiring a small charge, the number of pieces in the field could be greatly increased,—thus substituting for a small number of mortars of large calibre, of which each is often greater than necessary, an infinite

* By Bousmard, translated by Lieut. Tyler, R.E.

quantity of these little shells, equally destructive, and driving the men from the ramparts in all directions,—whereas in the former case, the fire must be confined to a few particular points at a time.

Coehorn employed these mortars for throwing shells into the batteries of the beseiged, destroying their platforms and gun carriages, enlarging and rendering more easy of ascent their breaches, bringing down their arches, and blowing up their magazines. See Plate. He made an equal number of improvements in the art of fortification; he constructed larger fronts and works than any of his predecessors, increased the number of flanks and intrenchments, and made the covered-ways twice as spacious; in fact, his system, admired by all who studied and understood it in his day, has, since his death, received that sanction which only time and the course of events could give it.

The siege of Bergen-op-Zoom, although wonderfully abridged by the valour of the French, was for all this so deadly and so lasting, as to afford to the conquerors a terrible lesson ~~of~~ on the merits of the fortifications, and the principles upon which they were constructed.

The first rule to which this illustrious Engineer attracts our notice is, that the strength of all fortification consists merely in obtaining the *means of cover* with a *flanking fire;* that is to say, according to him, these are the only *direct* and *positive* means by which this art can succeed: but there are other means, *indirect* and *negative*, as he calls them, which are not less efficacious; and Coehorn instances two of this latter kind corresponding to the first two. "The one is, to *confine*, and *create as many difficulties as possible on*, the ground on which the besiegers are likely to establish their batteries."—"The second is, to submerge the soil of their covered-ways and dry ditches, that they shall not be able to excavate any portion without the water coming in upon them; and they therefore would not be able to form lodgements without bringing materials to the spot, undergoing much delay, and conquering numerous difficulties, which must necessarily be met with in this species of work." Now it is very evident that this last condition can only be obtained upon marshy ground, or on plains a little above the level of the water, such as the greater part of the author's country. His whole system seems to be arranged upon the supposition, that the natural ground, or, in other words, the site upon which his fortress is constructed, is only 4 feet above the level of the water; and this situation seems to be quite necessary to enable him to surround his works with dry or wet ditches at pleasure. In the latter case, as the works immediately surrounded by water do not require any revetment, the expense is greatly decreased, and they are much more difficult to breach by artillery. He planned a space for manœuvring in the dry ditches which separated the unrevetted works from those which are revetted, at the gorge of the former, in which the troops forming a large front might await and drive back the besiegers, who could only cross by a bridge. There were also palisades with numerous gates, behind which to retire, and so cut off the pursuit of the enemy, in case of their throwing themselves into the ditch, with casemated batteries to enfilade it with artillery, and covered caponières to support them with musketry fire; also loopholed galleries at the gorge of the unrevetted works, from which all those entering the ditch could be seen in rear. For fear, however, that all these precautions would not serve to repulse the enemy, the larger work in rear of this dry ditch is revetted with masonry, and of such a height as to preclude all possibility of its being surmounted without scaling ladders, but so ~~weak~~ low that no portion of it ~~must~~ can be seen above the earthen-works in front of it. Such is the author's method of "obtaining cover." We will now proceed to analyze his plans for the flank defence of the wet ditches, that for the dry ditches having been already explained. This is done by flanks of

three different heights, two of which are defended by the fire from a large *orillon*, or segment of a circle, attached to the capital bastion and of the same height. This orillon takes up very little room, and contributes to the flank defence of three of the faces.

A counterguard of earth is constructed in front of each of the bastions, to afford cover to these three rows of flanks, merely thick enough to contain a shot-proof parapet and two banquettes, and insufficient for batteries, which, after having taken it, the enemy would naturally endeavour to establish.

The author proposes to obtain these advantages by the following construction. (*Vide Plan, fig.* 1, *and Sections.*)

On the bisections of the angles of a regular hexagon of 150 toises side, he lays off 75 toises, to determine the position of the flanked angles of the bastion, thus giving a total exterior side of 225 toises. On the interior side of 150 toises, he allows 37 toises 3 feet for the demi-gorge of each bastion, thus leaving a curtain of 75 toises in length. The lines of defence are drawn from the extremity of each demi-gorge, to the points before described as the flanked angles of the collateral bastions. From the flanked angle as a centre, and with the line of defence as a radius, an arc of a circle is described, which, cutting the other line of defence, determines the flank of the bastion, whose face is therefore that part of the line of defence between the flank and the flanked angle. This forms the large bastion entirely of earth, and having in front of it a wet ditch, 24 toises in width, and at its gorge a dry ditch, 16 toises wide. The parapet is only 20 feet thick at the top, and 7 toises on the level of the water, above which the crest is 16 feet, and 19 feet on a portion, 24 toises in length, measured on each face from the flanked angle.

In rear of the dry ditch are the faces of the capital bastion, revetted to a height of 16 feet above the level of the water, and therefore from 15 to 15½ feet above the bottom of the dry ditch. The orillon is constructed at the end of the outer face, to defend these faces and the dry ditch, by drawing a perpendicular 19 toises in length from the extreme point, and prolonging the face 8½ toises: at the other extremity of this perpendicular, a line is drawn 4 toises long, and parallel to the face of the bastion; then, at a distance of 5½ toises from this latter point, a third parallel betwen the face of the bastion and this last-mentioned line, 14 toises long. The extremity of this line is joined to the prolonged face of the bastion by an arc of a circle of 60°, and with the little side of 4 toises by a straight line, which completes the construction of the orillon. It is revetted, and is for that reason sometimes called by the author a *tour de pierre*, and is concealed on the three exterior sides by an earthen parapet, 16 feet thick at the crest, on the side which is perpendicular to the ditch, and 24 feet thick on the other two sides. The former is armed with six guns in a casemate, which enfilade the dry ditch, and communicates with a loopholed gallery placed at the gorge of the exterior face, and with numerous outlets into the ditch, for the retreat of those defending the work, and through which sorties may be made into the ditch. These outlets are secured with thick oaken gates, and the gallery itself is divided into compartments of 3 toises each, secured with similar gates, that the work may be disputed foot to foot with the enemy; and after having been thus employed, the enemy's lodgement on the outer face may be blown up by them.

A subterranean gallery or covered caponière, leading across the ditch on the capital, forms a communication between it and a gallery of mines, in rear of the escarp of the inner bastion, its bottom and sides being 3 feet below the level of the water; they are lined with cement up to that height, to keep it dry whilst in the possession of the besieged, and when forced to abandon it, they can fill it with water by opening a flood-gate to a small aqueduct constructed for that purpose. Its walls are only 2½

feet above the dry ditch, on the level of which loopholes are pierced, and the whole is covered over with $1\frac{1}{2}$ foot of timber and earth. There are at certain distances steps leading out of this caponière, and numerous staircases from the ditch to the top of the exterior face.

The orillon is separated from the dry ditch of the faces by a wet ditch, 6 toises wide, which is flanked by three guns placed behind a wall, 4 toises long and $2\frac{1}{2}$ feet thick: 12 feet above the water, and perpendicular to the large side of the orillon, a similar wall encloses the space which remains between this first wall and the revetment of the inner bastion. This second wall has a gate at each end, and two embrasures between them. These gates are closed by two draw-bridges, which rest upon bridges of stone by which the ditch of the orillon is crossed. One of these gives immediate access into the dry ditch, and the other leads into that portion behind the palisades intended as a retreat for the besieged, should the enemy pursue them into the dry ditch. The space behind the palisades is defended by two guns in the embrasures, which were before stated to be placed between the bridge-gates.

The portions of masonry of the orillon seen by the enemy are constructed in a very curious manner. Behind an outer revetment, sufficiently slight, numerous counterforts are built perpendicular to it, which extend to the foot of the subterraneous arches: these are crowned, and united by the arches, so that all the parapet and terreplein is supported by these; and in order to form a breach, either the arches must be destroyed by shells, or the foot of them by heavy guns. To render more difficult the destruction of the foot, and prevent the total descent of the earth, if the arches sustaining it happen to be damaged, the whole foot of the arches is united and propped up by two rows of vertical and concentric convex arches, at 6 feet distance from one another, which resist easily the pressure of the earth. A part of the exterior face joining the orillon, 8 toises in length, is revetted in the same manner, to support the slope caused by its height and projection, and by means of the masonry to stop the approach of the besiegers' miner towards it. The miner of the besieged has, on the contrary, many advantages of which he can make use in this masonry, viz. in misleading the enemy, or making "false holes," as the author calls them.

The flank of the inner bastion is only 15 toises in rear of the other, and has no terreplein, and but 10 feet of banquette, which may be increased, in case of attack, to 24 feet, by a timber footing supported on trestles. The entrance into the casemate, and subterraneous parts of the orillon, and the gallery of mines under the inner face, is from the dry ditch between the two flanks. The communication from this ditch to the interior of the Place is through a postern 10 feet wide, which passes under a part of the curtain perpendicular to the flank, and then leads through a large casemate containing four guns mounted on ship carriages, by which the ditch is defended.

The entire relief or total height of the capital works, bastions, and curtains, as well as orillons, is 26 feet above the supposed level of the water, or 22 feet above the natural ground. In order to give the flanked angles of the exterior bastions a musketry defence, for which purpose the flanks of the collateral bastions are too distant, perpendiculars are drawn at a distance of 140 toises from the flanked angles upon the lines of defence, and each terminating at its intersection with the line of defence from the opposite flanked angle. These perpendiculars are the flanks of the tenaille, the faces of which are composed of the parts of the lines of defence between these flanks and the orillons, and whose curtain is formed by the parts of the lines of defence between their intersection and the extremities of its flanks, thus broken, and forming an angle slightly salient. The flanks of this tenaille are kept as low as possible, to prevent their interference with the fire of the two others, and they are therefore not more than 7 feet above the water. Its faces are 12 feet high, to

preserve the flanks from plunging or enfilade fire, and its curtain is 12 feet, in order to protect the revetment of that in the rear of it, which is 10 feet high. Under the centre of the interior curtain is a postern 10 feet wide, to afford communication from the interior of the place to the dry ditch at the gorge of the tenaille. From this ditch the passage to the exterior is by boats, through the large wet ditch, by means of a trench full of water, at the foot of the middle flank, through an arched aqueduct passing under the face of the tenaille joining the orillon, and leading from this harbour into the ditch.

The main ditch being, as was before stated, 24 toises wide at its narrowest part, viz. opposite the flanked angles of the bastions, lines are drawn from the points thus fixed upon the shoulders of the orillons, and from their intersection 55 toises set off on each side will determine the demi-gorges of the demi-lune, whose faces are drawn from these points so as to form an angle of 60°. The work thus constructed is the earthen demi-lune, which is intended to protect the capital demi-lune of masonry, and from which it is separated by a dry ditch of the same width as that of the bastion, viz. 16 toises. This ditch is defended by the guns of the higher faces of the bastions, and those of the orillons, as well as the musketry from the lower face and from the two covered caponières which cross it at the distance of 5 toises from the main ditch. Each of these caponières is composed of two brick walls, a foot and a half thick, 7 feet high, and 8 or 9 feet apart: the wall on the side of the ditch is loopholed, so that the other wall, having two banquettes in rear of it, and being joined to the first by a covering of timber and earth 1½ ft. thick, the whole forms an ordinary parapet, and two rows of fire are obtained, the one above and the other below, out of the loopholes.

Two posterns at the extremity of the faces of the interior demi-lune lead to the space behind the caponières, into which the entrance is through two small gates: in front of these are two wet ditches, 6 toises wide, defended by loopholed galleries, 5 or 6 toises from their extremity, which are formed in the gorge of the exterior demi-lune, and are entered by two gates behind the caponières, and two gates in front of their small wet ditch, leading from the dry ditch of the demi-lune. There is another entrance into the dry ditch, but behind the palisades, driven in 4 toises from the escarp of the interior demi-lune, by a bridge thrown over the wet ditch of each caponière, and touching the escarp.

There is an underground communication across the ditch, on the capital of the ravelin, similar to that for the bastion. The descent into the interior demi-lune is through a postern under its flanked angle. This caponière leads to another which, on account of its size, is divided into three parts, and occupies the whole of the flanked angle of the exterior demi-lune for 12 toises, merely leaving room for firing over the parapet: it is pierced with loopholes all round, and covered with 3½ feet of timber and earth.

The relief of the lower demi-lune is in the centre of its faces, 14 feet above the water, 17 feet for a length of 24 toises on each side of the flanked angle, the better to protect the dry ditch and cover the caponières, and 15½ feet along 18 or 20 toises of the other extremity of the faces, to give sufficient height under their terreplein for the small galleries at those parts. The interior demi-lune is revetted with masonry 12 feet above the level of the water, thus keeping it 2 feet under the lowest part of the earthen parapet in front, and has a total height above the water of 18 feet. It has a terreplein, with no banquette, for a space of 20 toises on each side of the flanked angle, this part being destined entirely for artillery: the remainder of the parapet has two banquettes for musketry. The interior of this demi-lune is only 6″ above the water, and has at its gorge a harbour of a circular form, sloping out into the ditch, at the summit of which is a pentagonal caponière, in the shape of a small bastion,

whose faces and flanks are 5 toises each. The walls of brick are $1\frac{1}{2}$ ft. in thickness, loopholed all round, and the whole covered with 3 feet of timber and earth, of which the latter forms an elevated ridge on the centre. There is a staircase leading from the interior to the top, whence a fire of musketry can be kept up under cover of a brick wall raised on that of the caponière. The total relief of this little work is only 15 feet above the water, so that it is completely under cover of the demi-lune. It is separated from the remainder of the terreplein of the demi-lune by a row of palisades, parallel to its faces, and the extremities joined to the faces of the demi-lune. In the drawings of the author there appears to be a banquette raised behind the palisade, and it is supposed that his intention was to prolong it on each side during the defence, by small ditches across the faces of the demi-lune, directed on the extremities of the caponières in the dry ditch, which are dotted on the plan. Another row of palisades secures the retreat of the defenders of the former towards the caponières and the harbour.

In addition to the works already described, the author adds a counterguard for the bastion, whose gorge, entirely of earth, forms the counterscarp of it, the line of which was before determined: it is only thick enough to contain a parapet and two banquettes with the necessary slopes, constructed outwards from this line. The total relief above the water is 16 feet, and the base at this level about 9 toises. A wet ditch, 14 toises wide, in front of this work, extends to the ditch of the demi-lune, which is 18 toises in width.

The next work to be described is the covered-way, whose crest is 8 feet, and its terreplein, which commences at the foot of two banquettes in rear of the parapet, is 1 foot above the water, sloping down to the edge of the ditch, where it has only a height of a few inches above it. The width of the covered-way, measured from the crest to the ditch, is 12 toises. At each of the re-entering angles is a large place of arms, which is formed by setting off 25 toises along the crest on each side of the re-entering angle, and drawing the faces perpendicular to the crest. In every place of arms an intrenchment is constructed, allowing 13 toises on the line of the crest prolonged for demi-gorge, and drawing the faces parallel to those of the place of arms. The intrenchment consists of a loopholed brick wall, whose height is the same as that of the crest of the covered-way. The interval between the gorge and each branch of the counterscarp is closed by an earthen traverse, 18 feet thick in front of the intrenchment, with a parapet and two banquettes like those of the covered-way: the remainder of its terreplein is left free for manœuvres. To prevent the intrenchments from being blown up, or the traverses from being taken by assault, a row of palisades is placed in front of them, besides those on the interior slopes of the covered-way and traverses.

These palisades are of a construction peculiar to the author: strong stakes are driven into the ground at certain distances, and connected by horizontal pieces made to revolve, and stuck about with short lances, the points of which will thus be some upwards and some downwards. This mode of construction is attended with many advantages: being already in store, they may be more quickly set up; they can be taken down while under fire from the enemy, and replaced at the moment of assault; they are also more convenient for making sorties.

Anxious to prevent the besiegers from approaching his traverses and intrenchments, which the smallest guns brought to the crest of the re-entering places of arms would destroy, the author constructed caponières parallel to the faces of the latter, 8 feet wide, 6 feet high, and at 6 toises distance from the crest, sunk into the glacis, and covered over with 1 foot of timber and earth, and $1\frac{1}{2}$ ft. above the level of it. The descent into them is through two little passages covered and constructed in the

same manner, 3 toises from the junction of the faces of the place of arms with the branches of the covered-way. The palisades also of the faces are prolonged in front of the traverses, across the covered-way to the ditch, with gates for the ingress and egress of the defenders.

SECTION II.—EXAMINATION INTO THE ADVANTAGES AND DEFECTS OF THE PRECEDING SYSTEM, WITH CHANGES IN ITS CONSTRUCTION, FOR THE PURPOSE OF AUGMENTING THE FORMER AND DIMINISHING THE LATTER.

There is one great truth which, greatly to Coehorn's credit, he alone, of all modern Engineers, has established; viz. "that the same system of fortification cannot apply to places with wet as to those with dry ditches."

In the former case, high escarps of masonry, which were invented with a view to security from those works in the ditch to which the enemy might gain access, are merely a useless expense; besides which these escarps are more easily destroyed by artillery than those of earth, and when they fall, leave the parapets they were intended to support without a base, and consequently without defence. The masonry revetment is then a necessary evil in a work with a dry ditch, which might otherwise be taken by assault, and would be an inexcusable defect in a work with a wet ditch.

On the other hand, the difficulty of communication with, and retreat from, a place surrounded by water, makes the defence less vigorous, and of shorter duration: the conveyance of reinforcements of men, arms, and ammunition, can be neither in time nor proportion to the want of them, as in a work where you can travel from any one part to any other part on foot; and the fear of being assailed too quickly, and in too great force, to give the besieged time to escape, causes these works to be abandoned sooner than they otherwise would be. This assault is much to be dreaded, and no intrenchment can be safe against it, as the assailants are able to form in line along the slope of the earthen escarps; and this defect, applying to the body of the place, when its escarps are also of earth, is even of more serious consequence than the detached works. Whence we see that we must arrive at the intrenchments in front of the breaches, in order to discover an excuse for masonry revetments with wet ditches.

It seems then that an Engineer reduced to the necessity of fortifying a work with wet ditches, has but two evils between which to choose: either to make expensive revetments, useless when breached in protecting his works from sudden assault, and not at all likely to keep the parapets standing or defensible; or to construct works which, whatever intrenchments may be made, will not be secure against assault, as soon as the passage of the ditch is completed by the enemy.

It is, however, this double necessity, the evil of which Coehorn has not only avoided, but turned to his own advantage. The large dry ditch behind his earthen-works deprives them of all fear regarding their retreat and communications; and the work revetted with masonry, serving as an intrenchment to the former, cannot, like it, be taken by assault. Neither can the earthen-work itself; for if the besieger should arrive there and remain on the parapet or narrow terreplein of the work, he would find himself in a "wasp's nest;" or if he were to leap down into the ditch, he would there be surrounded by the fires of the galleries, caponières, and casemated batteries defending it; or should he attempt to form a lodgement thereon, he would be blown into the air by the mines ready prepared underneath the gorge. On the other hand, the revetted work in rear, properly called by the author the "capital work," having its masonry below the earthen-work, remains consequently unhurt, so that even a breach in the latter would not expose it to the fire of the besiegers; and it is no less difficult to breach it by means of mines, and the end of the passage of the ditch, and across to the gallery, which is prepared with small mines to give a warm reception.

The only other means by which this breach could be conveniently made, besides those we have described, are, by discharging a number of small mines, or throwing shells from a distance, in which case the operator would be out of the reach of the galleries of the besieged.

At the same time that these dry ditches behind the earthen-works are so much in the besieger's way, when he has arrived thus far, they afford ample means of annoying him while endeavouring to retreat. Guns, mortars, and howitzers, could be brought to bear upon all his works, while those serving them would be under cover, in addition to the direct fire of the capital front. Besides this double row of fire, is that of the covered-way, the width, size, and facility of communication of which allows of all sorts of pieces being employed on it, in a position nearer to the enemy, and therefore still more certain and deadly in their effects.

The musketry fire is also very destructive in this system, from the covered-ways, as well as from the counterguards and lower works, entirely devoted to this purpose. The fire from the caponières in front of the re-entering places of arms forms a third row of musketry, although the besieger could in a great measure destroy these from his first batteries, or those of the second parallel.

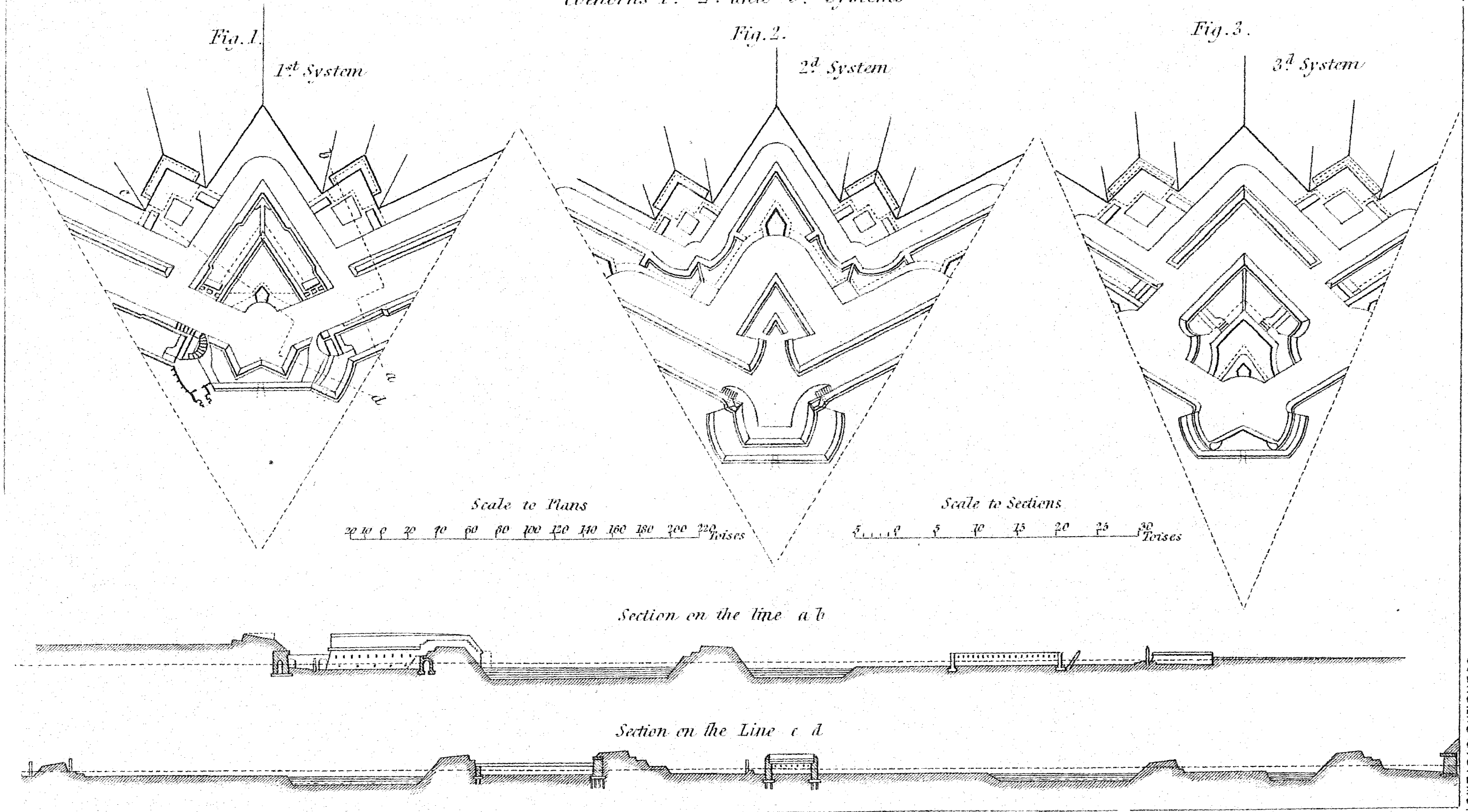
It certainly would not be possible to contain in such a place as the preceding, supplies of men, arms, or ammunition, sufficient for the continuance of these numerous fires of every description; but it is, at the same time, a great advantage to be provided with these works, which can be made use of according to circumstances.

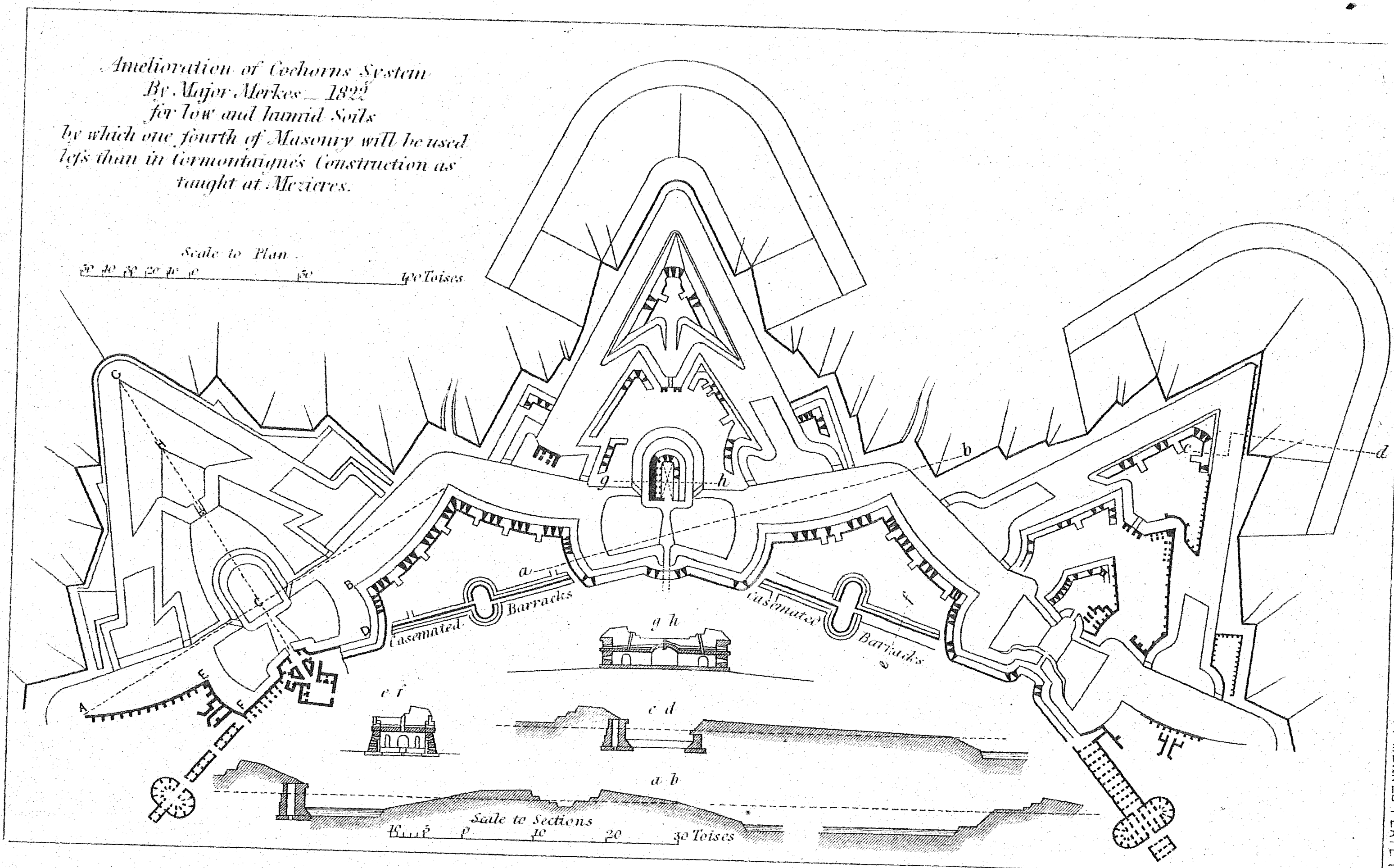
The advantages of this system are general, and result necessarily from the marshy ground on which it was intended to be applied; but its defects, with the exception of one, consist for the most part in the economy of expense, which the author has endeavoured to decrease by a number of petty means. His caponières and galleries with small walls, and covered with timber and earth, would not resist the smallest shell, or even ricochet fire, any more than the masonry intrenchments of the re-entering places of arms. The communications on the capitals buried under the level of the water have a still greater defect, as they would be flooded by the smallest breach being made in them. The other works, which are not proof against the weapons of the besieger, are of no use but to retreat to for a short time; they also do much harm, by the discouragement they give to soldiers, and even to officers, who despair of the works they have to defend, in as much as those they have lost deceived their expectations.

The principal defect before alluded to consists in the position of the orillon, which, being the only defence for the ditch between the two faces of the bastion, leaves it entirely undefended, as soon as it is destroyed by a few cannon-balls, thrown at the foot of the casemate, and lies but an inert mass, its only use being to protect this ditch from the fire of the flanks of the opposite bastion, from which it might otherwise be seen.

With a view, no doubt, of correcting this error, the author established his second system, in which (fig. 2) the orillons placed at the ends of the faces of the capital bastions afford cover to the inner and middle flanks, without interfering with the defence~~s and~~ of the dry ditch, from the flanks of the collateral bastions. Another advantage of this construction is that of a free communication, throughout the body of the place, by a dry ditch, of which the width is increased to 20 toises instead of 16, as in the first system. Caponières are placed in the capitals of the bastions, as before, and loopholed galleries under the gorge of the earthen counterguards at the extremity of the dry ditch, at 16 or 17 feet above its surface, to give the use of this communication to all forces, and even to cavalry, of which the author reasonably

Coehorns 1st 2d and 3d Systems




Amelioration of Coehorns System
By Major Merkes _ 1822
for low and humid Soils
by which one fourth of Masonry will be used
less than in Cormontaigne's Construction as
taught at Mezieres.
Scale to Plan.
50 40 30 20 10 0
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Casemated Barracks
Casemated Barracks
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Scale to Sections
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30 Toises

proposes to make use in driving the enemy out of the ditch. The ravelins are constructed with retired flanks, joined to the continuation of the exterior faces of the bastion, and at the extremity of the flanks is a casemated redoubt, separated from each of them by a small space closed by a gate, formed of loopholed walls, and covered with timber and earth. There are loopholed galleries of the same description in the faces and flanks of the ravelin.

A second most essential difference is that between the first counterguard, in every respect similar to that of the former system, and the enceinte and ravelins which we are about to describe: there is another counterguard, like that of the counterguards in the first system, and a wet ditch, 14 toises wide. This second counterguard, or rather surrounding earthen parapet, is separated from the first enceinte by a wet ditch, 24 toises in width, with traverses drawn upon the lines of those of the first counterguard prolonged, and having masonry intrenchments in all its salient and re-entering angles. The communication to them is through a gallery in the rampart on the capital, which, like those of the first counterguard and dry ditch, is only 6 inches or 1 foot above the level of the water. The retreat of the defenders, from every part, is secured by palisades, 3 toises from the gorge of this second counterguard: the communication through them to each of the masonry works is intrenched, and similar palisades constructed 4 toises in front of the capital bastion, as in the first system. There is before the curtain a tenaille with flanks, from which a third row of fire is obtained as before. It is separated from the dry ditch in front of it by a wet ditch, 10 toises wide. We will now say no more of this system, as the Plate shews it plainly, but that it is applied, according to the plan of the author, to a heptagon whose interior side is 126 toises. The reliefs are almost the same as before, the only exception being that the interior faces and flanks of the bastions are 6 feet higher, that they may see the crest of the glacis over that of the second counterguard, which takes up more space, and is further from them than the counterguards in the first system.

The same reasons, of facilitating the communications and lessening the openings on the body of the place, which were considered the improvements of the second system over the first, are doubly so over the third, which (fig. 3) is even more faulty in these two essential points. The dry ditch of its detached bastions has, in like manner, the defect of being masked by the orillons, at the extremities of the inner faces of the bastions, though at the same time it is, in this system, of less consequence.

This third system presents in detail the same front in its detached works as the first: the only parts not employed in it are the curtain and the third row of flanks. Besides, there are a few others in the minutiæ.

1st. In addition to the caponière placed in front of each of the re-entering places of arms of the covered-way, called by the author "redan," he places at the interior slope of the parapet of this place of arms a loopholed gallery, and consequently the palisades of the covered-way are, at this portion of it, 2 toises in rear of its crest.

2ndly. In front of the caponière, at the gorge of the principal ravelin, there is a dry ditch, with two branches to the faces of the ravelin, in front of the two arched outlets, and leading to the earthen counterguard, which are directed on its caponières.

3rdly. At the gorge of the detached bastion there is a similar caponière, surrounded by a dry ditch, at the counterscarp of which is a loopholed gallery. Now he seems to imagine that all this complication of means must increase the good effects.

Behind this system of detached works is the body of the place, formed of bastions with the usual orillons, revetted, with double flanks but single faces, joined by double curtains, of which the lower is broken up as before.

Between these two curtains, at the narrowest part, there is a small harbour on each side, from whence, through arched passages, under the exterior curtain, a communication is kept up with the exterior works, at the gorge of each of which is also a sort of harbour, with circular slopes.

The body of the place is so constructed that the points of its bastions are directly in rear of the centres of the gorges of the ravelins, and a wet ditch, 20 toises in width, runs between their faces and the parallel gorges of the detached bastions.

H. W. T.

THE FRENCH OR BASTION SYSTEM.*

SECTION I.

Vauban's trace, which differs but slightly from that of Pagan, (see Plate I. figs. 1, 2, 3, and 4,) may be considered as the basis on which the Bastion System is founded; the principal feature of which is the depth of relief, or command of the country (25 feet French).

Cormontaigne, profiting by the experience and the views of the illustrious Engineer who preceded him, made some essential changes in the construction of the Bastion System, (see fig. 5 of Plate I.,) more especially in the relief, and thus gave better cover to the body of the place. This, which is termed *fortification rasante*, and adopted by him, has become the distinctive character of the modern school.

Lieut.-Colonel Duvignau, who taught at the school of Metz until the year 1793, improved upon Cormontaigne, by extending the salients of his ravelins and giving casemated flanks to his redoubts. And the systems of Dobenheim, Lesage, and Col. Noizet, proposed several other changes as now taught, (see fig. 6, Plate I.) In fulfilling the principles of Cormontaigne, they remedied the defect of the opening of the ditch of the ravelin, as likewise in the construction of the retrenchments in the bastions. About the year 1808, Bousmard and Chasseloup proposed their systems of placing the ravelins beyond the glacis; but the modern French school never adopted them, and preferred adhering to the principles of Cormontaigne, giving them all the improvements of which they are susceptible.

Among these is that of General Dufour, now Major-General of the Helvetian Confederation, (see Plate II. fig. 1.) This Engineer directs the faces of the ravelin according to the modern practice; and at the salient angle, extending 20 toises on each face, he places what may be called a cavalier, (see fig. 2, Plate II.,) which covers the ravelin by a break in the crest of the terreplein of 4 toises, and thus preserves them from ricochet, by the shelter which the cavalier on the salient angle affords them,—presenting to the enemy a dead mass of earth, on which it would be useless to expend his shot, and yet impracticable to establish a lodgement thereon, whilst it effectually covered the ravelin. The flanks of the redoubt of the ravelin have no terreplein, but consist of loopholed walls, with sally-ports sufficiently large for the passage of artillery; consequently the flanks are only adapted for musketry fire, for by this system the body of the place is not exposed. General Dufour proposes to close the ditch of the ravelin by a species of tenaillon, which he covers by a glacis, so that its escarp cannot be seen: this supersedes the necessity of a redoubt in the ~~returning~~ re-entering place of arms of the covert-way. It must be admitted that this construction obliges an enemy to crown the covert-way of the bastion attacked.

* Taken from an 'Essai sur la Fortification Moderne,' par le Baron Emile Maurice, Capitaine du Génie.

SECTION II.—OF THE SEVERAL MEANS TO ADD TO THE VALUE OF THE BASTION SYSTEM.

The fausse-braie, among the various means proposed, not only to correct the trace of the bastion, but to add to its defence, is the most defective, as it divides the body of the place into two stages, and facilitates escalades; and the lower level is untenable when the vertical fire of the besiegers commences, affording no command over the glacis. This description of fortification has been wholly abandoned in modern works. The fausse-braie must not be confounded with the *chemin des rondes* between the escarp and the parapet, which also were used in the old constructions, affording a good protection to the ditch and counterscarp by musketry fire. Vauban regretted bringing the chemin des rondes into disuse.*

Retrenchments in the Body of the Place.—That en cavalier (see Plate I. fig. 6) to be used when the bastions are large, and when a good command is desirable; but as they cramp the deployment of troops in the defence of the breaches, they should be constructed rather in the collateral bastions of the probable front of attack, and are thus judiciously placed in the forts at Lyons and Paris. The *retranchement tenaillé*, from the angle of the shoulder, is another resource for the defence of the breach, but also cramps too much the interior space of the bastion, (see figs. 2 and 3, Plate III.)

The *retranchement bastioné* is preferable, particularly if it occupies the gorge, when it does not encroach on the bastion.

SECTION III.—ADVANCED AND DETACHED WORKS.

Hornworks—when established in front of a ravelin, expose the body of the place, (see fig. 1, Plate IV.;) but placed before a bastion, this inconvenience does not arise, (see fig. 2, Plate IV.,) although it only removes the defect; for when the ravelin is taken, the angle of the shoulder of the bastion is exposed, instead of the salient. Besides, the hornwork, once taken, affords to an enemy, by the width of the terreplein, plenty of space to effect his lodgements. However, *hornworks* and *crownworks* serve to occupy ground in advance, which accidental circumstances render inconvenient to leave to an enemy, but they are preferable when constructed beyond the glacis; of which there are good examples at Romainville, at Noisi and Rosny at Paris, at Fort Vitriolerie at Lyons, and at Belle-Croix at Metz.

Lunette de Darçon.—The disadvantage of all advanced works has arisen from the difficulty of so constructing them as to render them independent: lunettes may have their faces and glacis flanked from the rear, but it is almost impossible to guard against a surprise† by the gorge. This defect General Darçon proposed to remedy (see Plate IV. figs. 3 and 4) by a circular tower, called a réduit de sûreté, not for the purpose of securing the garrison of the lunette, but to protect its retreat to the body of the place. The casemates secure the garrison also from vertical fire, and the ditches of the lunette are flanked by a reverse fire in the counterscarp. But the circular tower has no command over the country, and the summit is not constructed for artillery; and there is no covered communication with the body of the place. Plate V., figs. 1 and 2, represents a modification of the foregoing project, supplying, at the same time,

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* See Jones's 'Sieges,' Note 25, vol. i. † Ibid.

improvements of which the lunette is susceptible. The first consists in the construction of the circular réduit, so that a good command is obtained, and the arches are sufficiently strong to carry heavy artillery; the floor below the summit is loopholed, to see the terreplein of the redoubt, and command the glacis of the gorge. The flanks and faces of the lunette are flanked by a reverse fire in the counterscarp.

SECTION IV.—BATTERIES CASEMATED À L'HAXO. TRACE OF CHASSELOUP.

Casemated Batteries à l'Haxo.—It does not appear that any trace can be found, even in Vauban or Cormontaigne, where the profile can be preserved for defensive purposes. The modern French Engineers have attempted to secure the fire of artillery without being so plunging as those en barbette, or so low from casemated batteries in the flanks of the bastions, and yet have the advantage of being hidden, to a certain extent, from the enemy. And, instead of piercing the massive parapet with embrasures, a *casemated battery à l'Haxo*, the name of the inventor, is raised above the crest of the parapet on the terreplein, (see Plates VI. and VII. figs. 1, 2, 3, and 4.) The artillery, thus sheltered, has all the advantages of casemated batteries without the inconveniences attending them, such as the masonry being exposed, and the danger from splinters; as the embrasures are revetted with fascines, and the arrangement of the arches gives security from vertical fire, and a free circulation of air.

Chasseloup's Trace.—Le Général le Marquis de Chasseloup is the author of a system represented in Plate VIII.: without going into minute details, it will be sufficient to explain, that it embodies the following advantages:

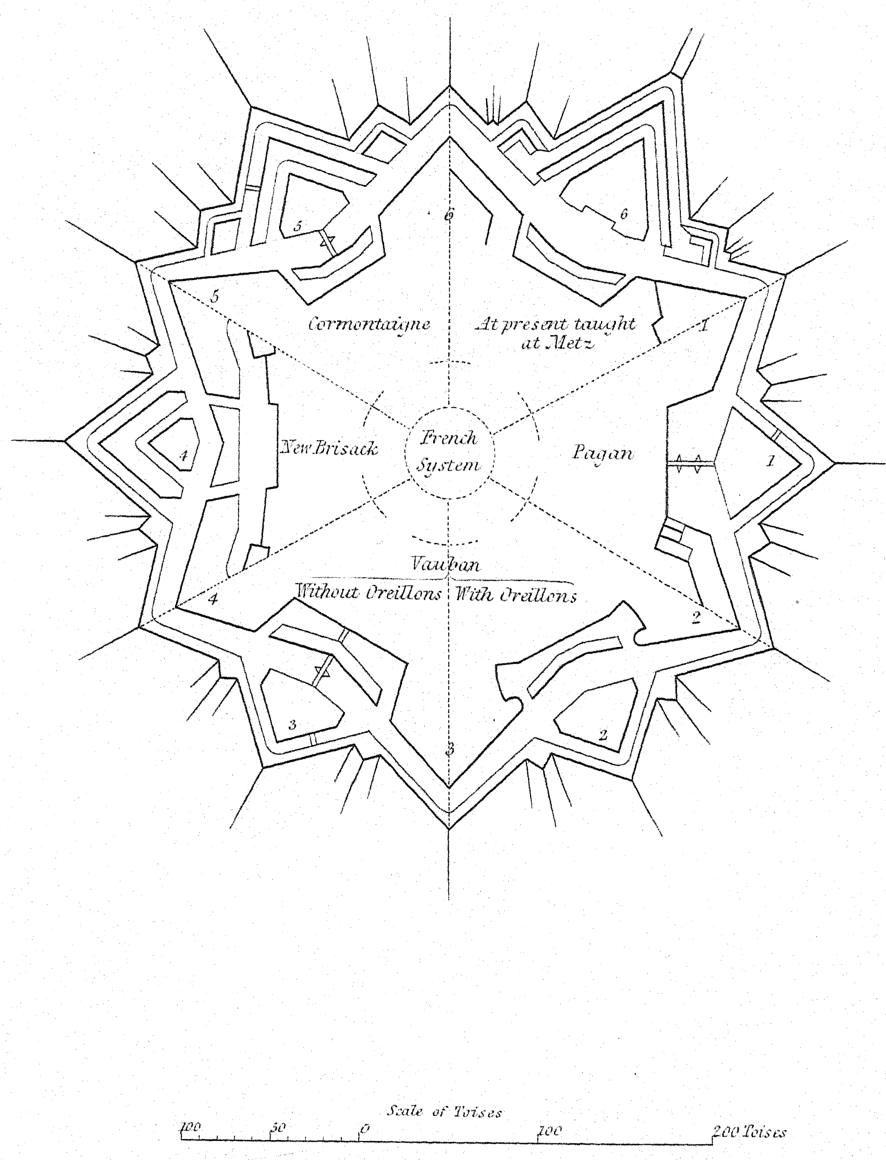
1. That of keeping the enemy at a distance by means of outworks, well supported by the body of the place.
2. Of giving every facility to sorties.
3. Of obstructing the advance of the besiegers, by means of the casemated réduits in the advanced ravelin and covert-way.
4. Of securing the two covert-ways from ricochet.

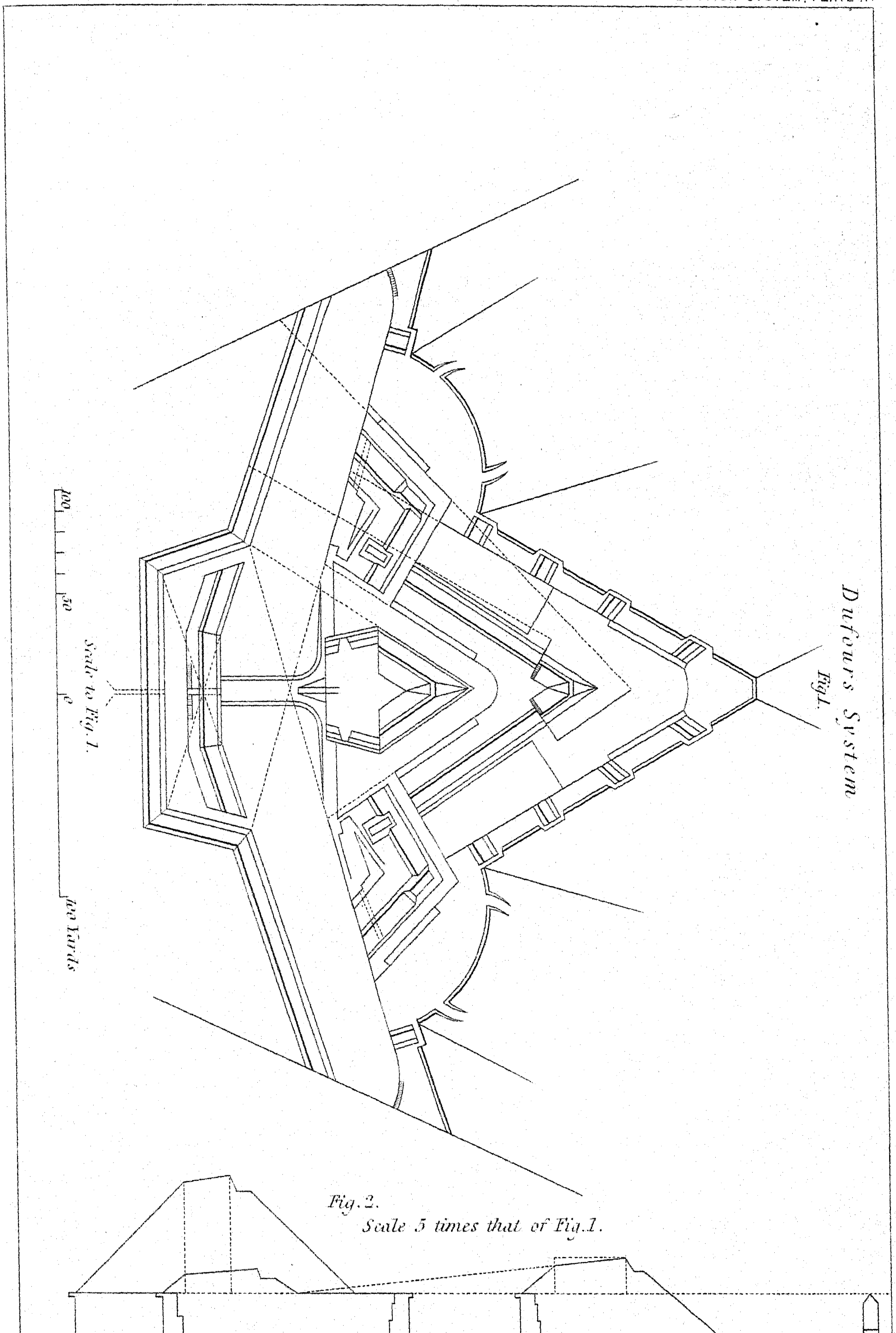
The trace, of which Plate VIII. explains the project, has the exterior side ($x\ y$) 600 yards; but the faces of the bastion are broken, as shewn at m and v. The flanks (n, o) have a line of defence equal to 400 yards, which is very great, considering that musketry is only effective at 200 yards. The small faces of the bastions (x, $m \times v$, y) are 70 yards; and the larger (m, n, v, n) are 170 yards. To construct the curtain, z, l is made equal to $\frac{1}{8}$ of x, y; and the flanks are constructed perpendicular to the line of defence; the salient of the ravelin is formed by extending it 250 yards from the front on line x, y; and the faces cover the bastions 100 yards from the angle of the shoulder. The salient of the caponière (s) extends 100 yards beyond the line x, y, at s; and the faces are directed 50 yards from the angle of the shoulder.

The glacis ($g\ g$,) of the body of the place masks the latter from the openings of the ravelins, as well as the flanks of the caponière; and it is impossible to enfilade the covert-way. And thus the besiegers must take the outworks, or advance between the ravelins, and these being taken in reverse, the casemated réduit, as shown at l, s, sees into the ravelins, and the réduit of the ravelin gives still further security to the latter, which must be reduced before the body of the place is attacked.

This trace will be found to possess some resemblance to that of Bousmard, given in his Supplement to his 'Essai Général de Fortification;' but he made his bastions

Trace of the Principal French Systems used in the construction of Fortifications during the last 2½ centuries.





E. C. de M. del.   J.W. Lowry fc.

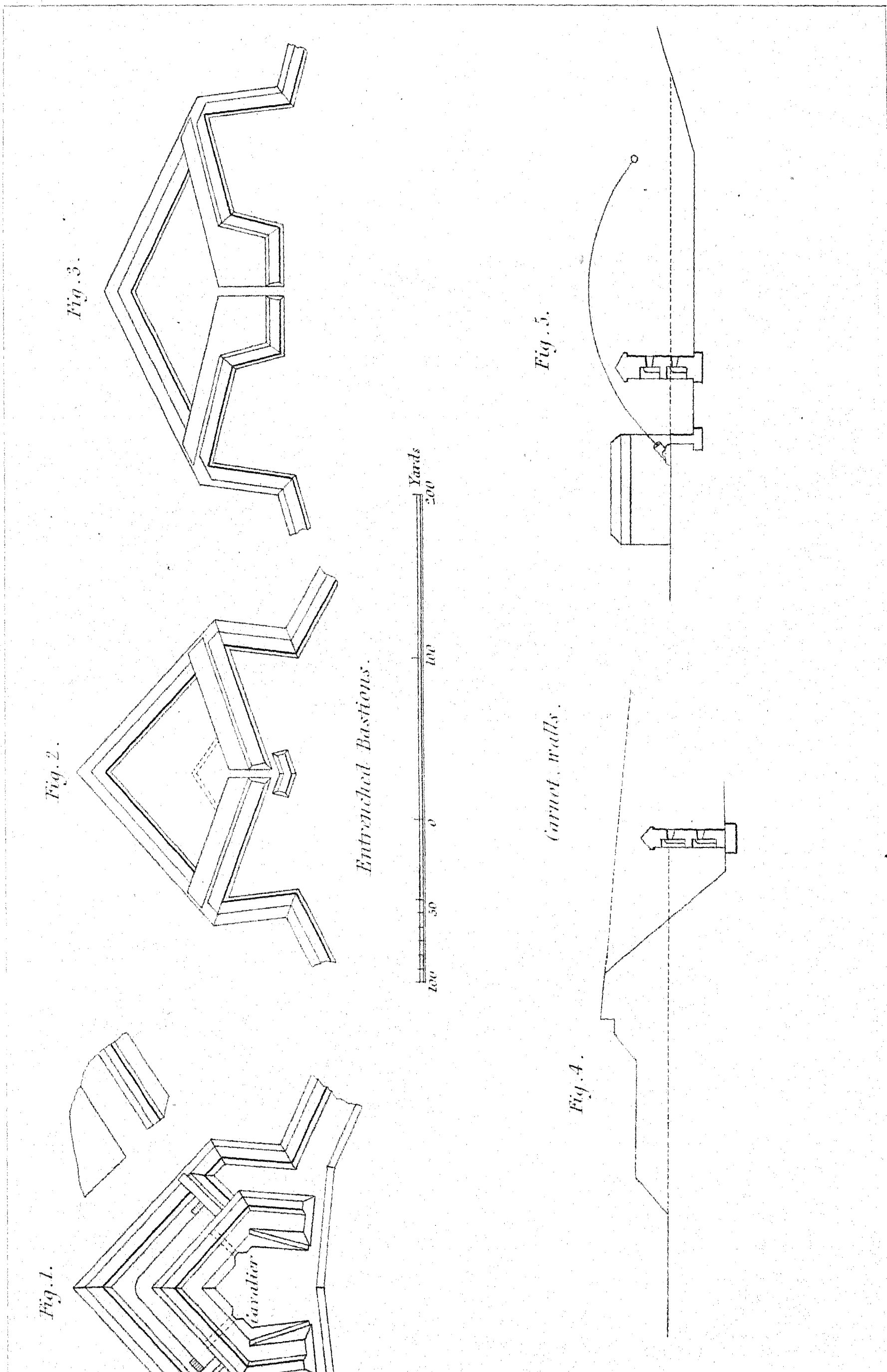


Fig. 1.
Cavalier
Fig. 2.
Entrenched Bastions.
Fig. 3.
100
50
0
100
200
Yards
Fig. 4.
Carnot. walls.
Fig. 5.

E.C. de M. del.

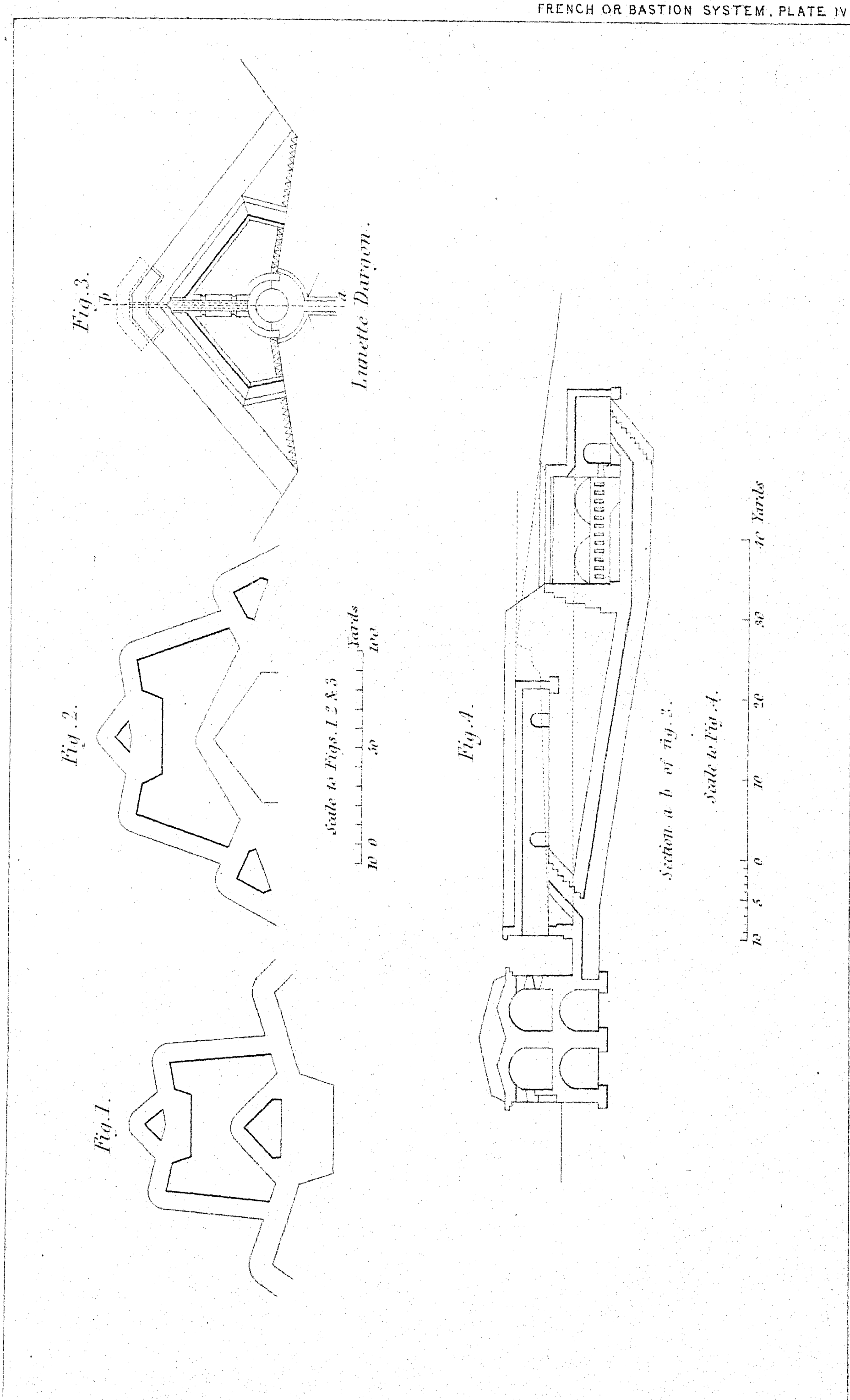
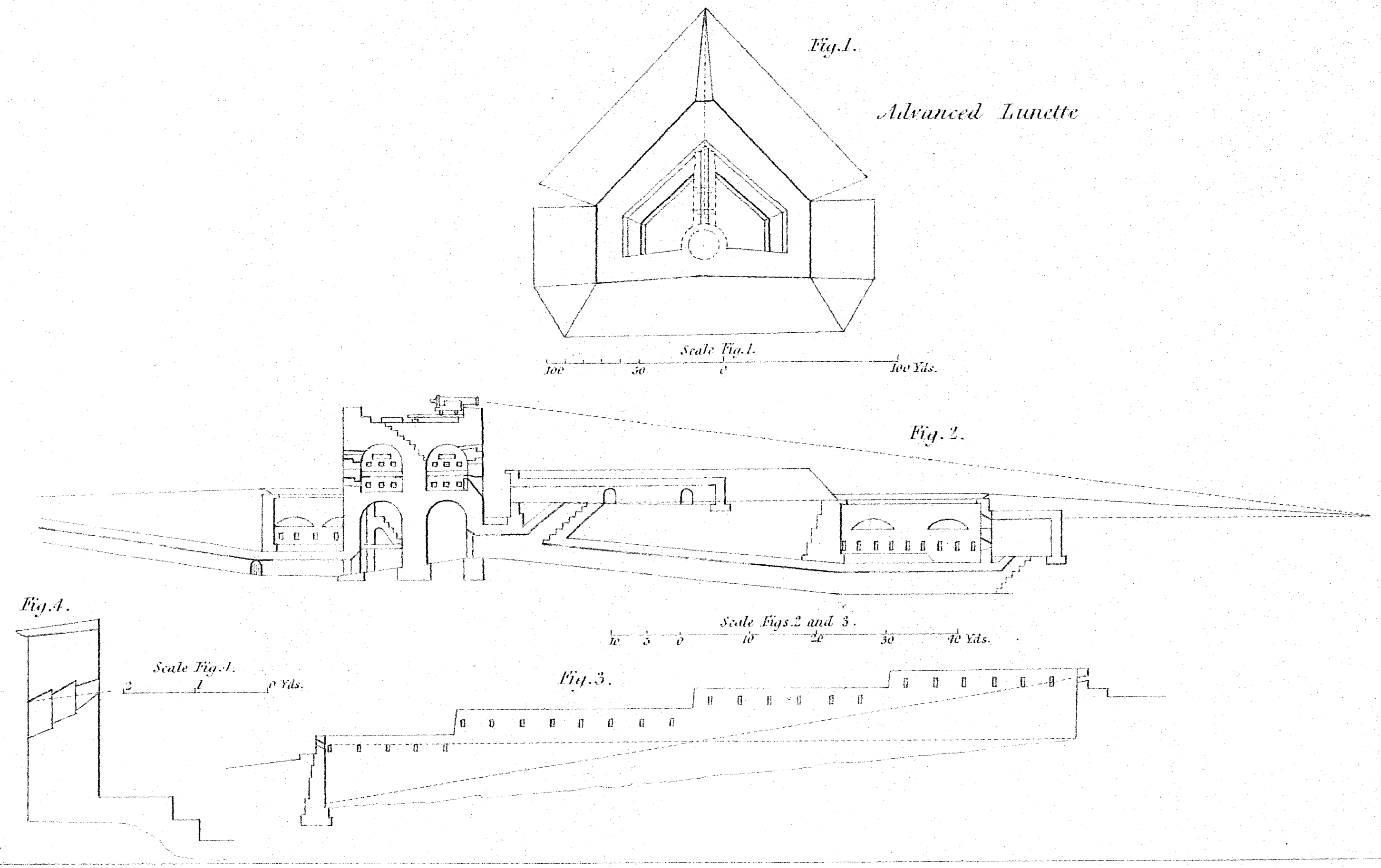


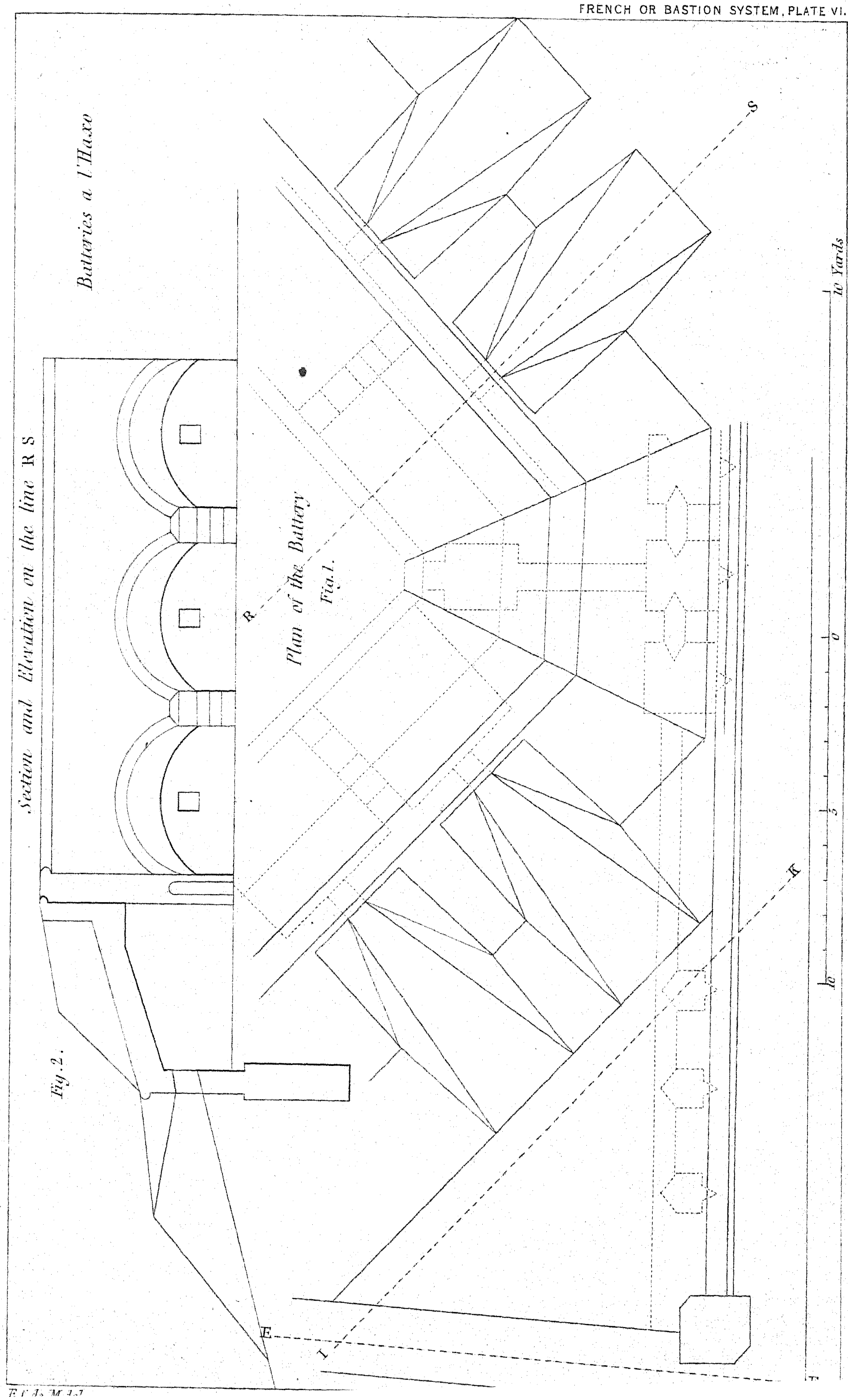
Fig. 1.
Fig. 2.
Fig. 3.
b
a
Lunette Darçon.
Scale to Figs. 1, 2 & 3.
10 0 50 100 Yards
Fig. 4.
Section a b of Fig. 3.
Scale to Fig. 4.
10 5 0 10 20 30 40 Yards

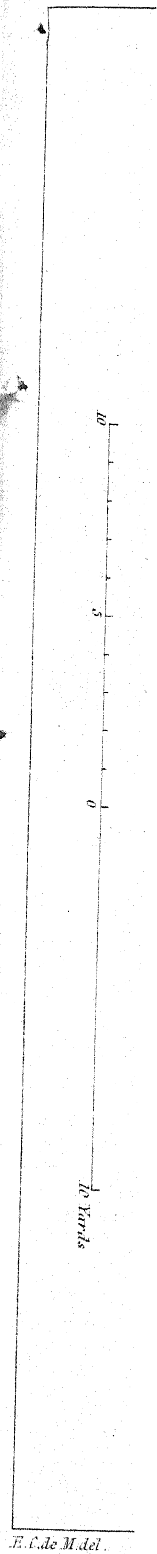
J.W. Lowry fc.

Advanced Lunette

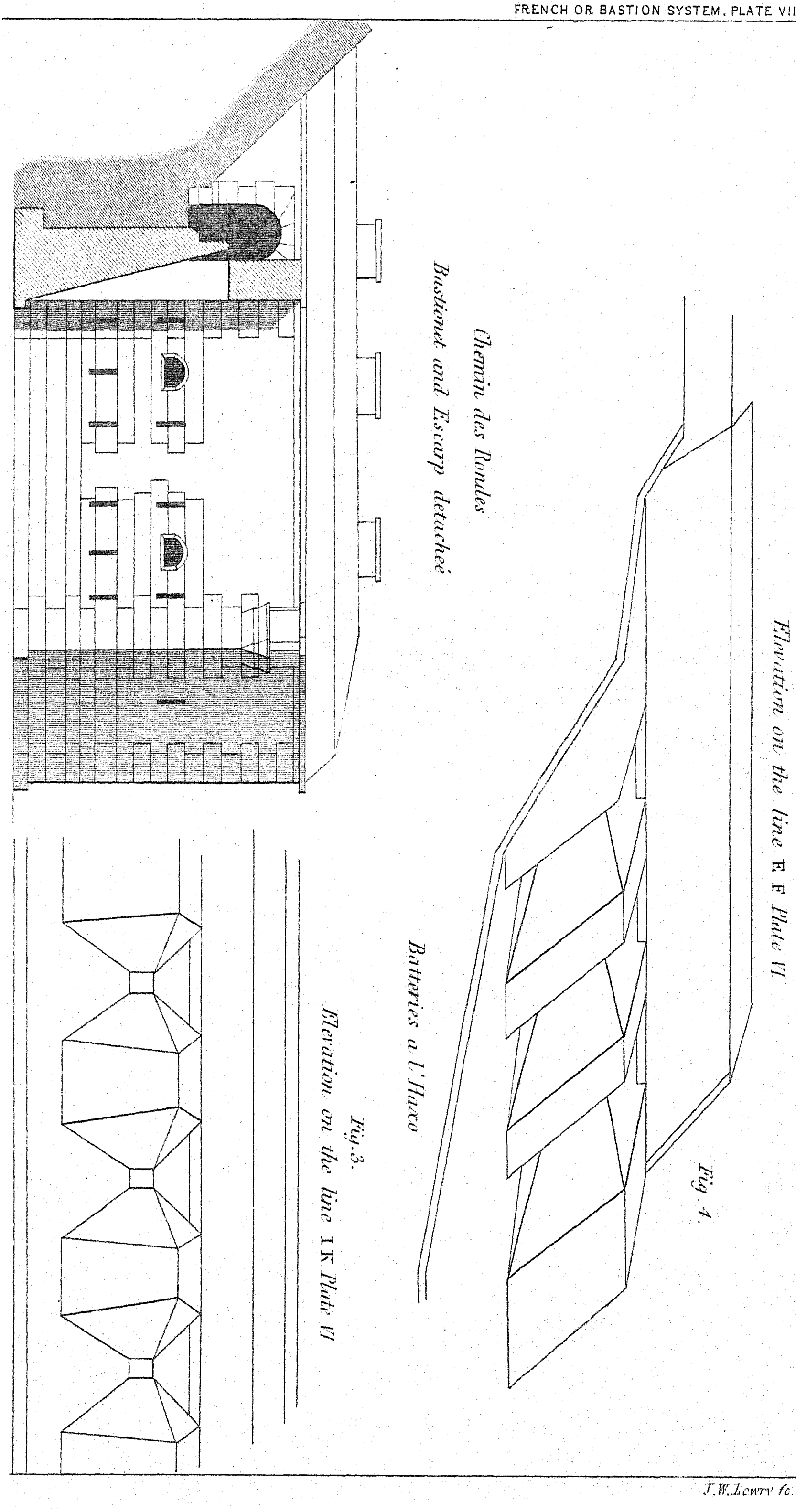


A. C. del.

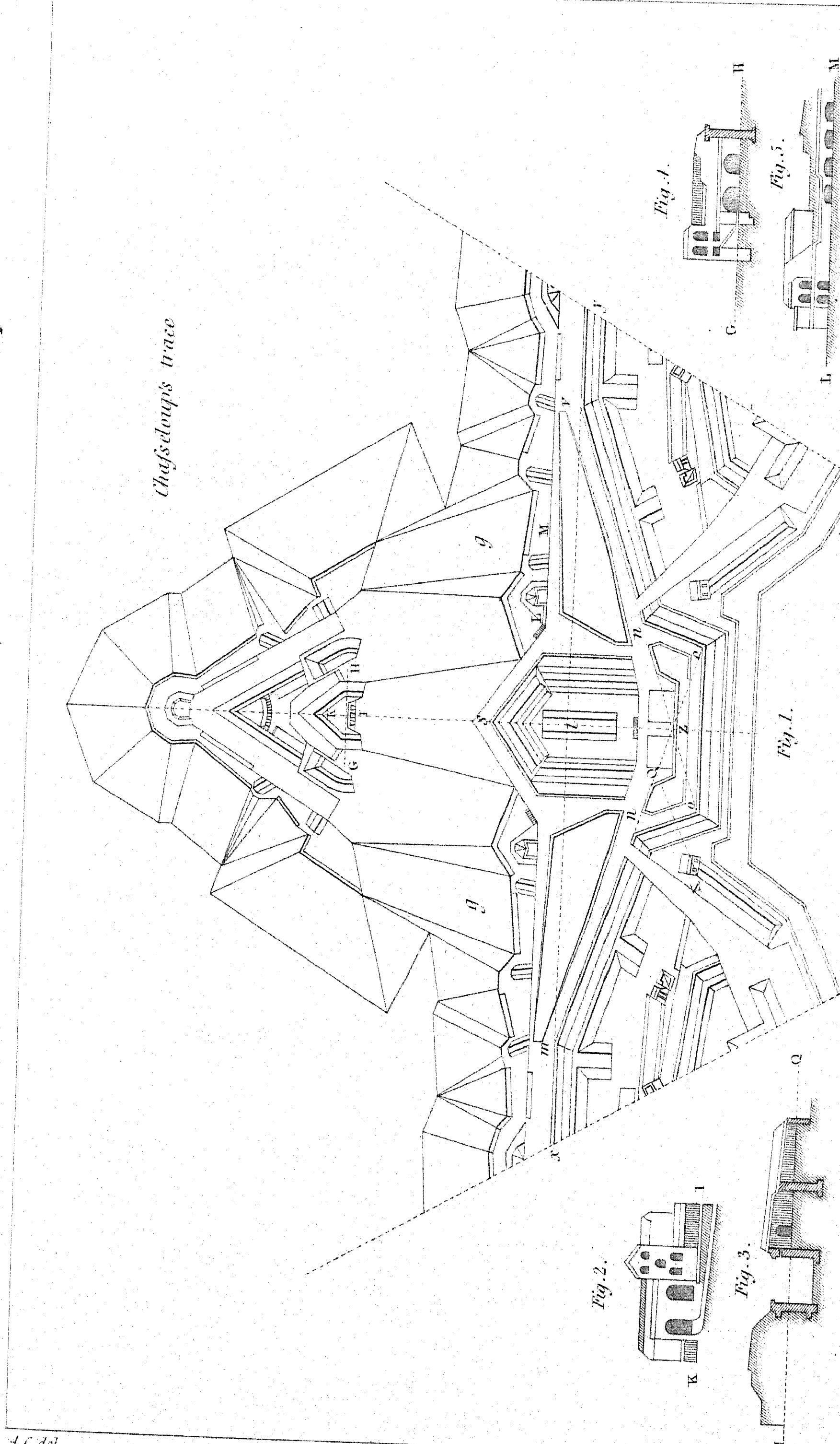

Batteries a l'Haxo
Section and Elevation on the line R S
Fig. 2.
Plan of the Battery
Fig. 1.
R
S
K
E
I
10 Yards
0
5
10



E. C. de M. del.


Chemin des Rondes
Bastionet and Escarp detacheé
Elevation on the line E F Plate VI
Fig. 4.
Batteries a l'Haxo
Fig. 3.
Elevation on the line I K Plate VI

J.W. Lowry fc.


Chafseloups trace
Fig. 1.
Fig. 2.
Fig. 3.
Fig. 4.
Fig. 5.
0 50 100 200 300 400 Yards
A.C. del.

curvilinear. Chasseloup adopted the polygonal form, and his advanced covert-way has the disadvantage, like all other advanced covert-ways, of not being protected from the body of the place; and the opening, to secure the retreat of the garrison, when the ravelin is taken, is not so well contrived as Bousmard's; but the system of Chasseloup has been applied to the defence of Alexandria in Italy, under Napoleon: however, since the Peace of 1814, they have been destroyed. More detailed drawings may be found in Captain Macaulay's (R. E.) description of the works at Alexandria.

SECTION V.—CONCLUSION.

It is only now necessary to analyze the Bastion System, as to what characterizes the modern school, freed from routine and precise terms, making the study of the ground and the defilements the basis to work from, and which directs that the masonry of the works be well covered, that the outworks extend as far as possible, so as to oblige the enemy to capture them, or be liable to be taken in reverse as he advances. And under the protection of these salients, the system admits of sorties and tactical operations.

It may be said that the casemated cover is too small and insufficient, whether in the flanks, or as reverse fire in the counterscarps, as likewise that the system does not admit of sufficient armament on the front of attack. It is true that only 70 pieces of artillery are provided for by the rules of the Service; but taking the system of Noizet, shewn in Plate I. fig. 6, it will be found that it is possible to unite 160 guns and howitzers, and about 40 mortars, on the front of attack; as for example—

At the salients of bastion attacked	1
Twelve pieces to each face	24
Eight pieces to each flank	16
Five to each face of the cavalier	10
Twenty pieces to each collateral curtain, protected by blindages	40
One howitzer in each salient of ravelin attacked	2
Eleven pieces to each face of ravelin attacked	22
Two pieces in the re-entering place of arms	2
The two collateral bastions of the front of attack, five in each face	10
Four pieces to each flank of those bastions	8
Collateral ravelins, six for each face	12
Re-entering place of arms, with 6-inch howitzers, about	16
Mortars and pierriers in the curtains and bastions, about	40
	203

A certain number of these, to be covered by casemates à l'Haxo, which serve also as traverses, will be preserved infinitely better than those proposed by Montalembert.

The defects of the Bastion system, by exposing the body of the place through the ditch of the ravelin, is modified, as proposed by Noizet and Dufour, (see Plate I. fig. 6, and Plate II. fig. 1,) and the enfilade to which it is subject is removed by the projects of Dufour, Chasseloup, and Bousmard.

The improvements in gunnery by the introduction of Congreve's rockets, the perfection of Shrapnell's shells, and the invention of Delvigne's carbine with the cylindro-conical ball, which will carry from 1000 to 1200 yards, against which no sap could advance, and finally, the heavy guns of General Paixhans, of 8 and 10-inch diameter, which carry from 2000 to 3000 yards, must all be considered, as they will have a considerable influence on the attack and defence of places.

MONTALEMBERT'S SYSTEM.*

Mark René, Marquis de Montalembert, a French General, born in 1714, entered the service at eighteen, and assisted at the siege of Kehl in 1733; afterwards he was attached to the Swedish army during the seven years' war, where he saw the towers of the Swedish General Carlsberg, and from them he conceived the idea of his casemated towers. In 1776 he published his work on 'Perpendicular Fortification, or the Art of Defence rendered superior to the Attack of Places.'

The principles on which Montalembert based his system were violently attacked by the French Engineers, but Carnot adopted them, and the German System † has admitted their advantages, and followed them.

The trace (see Plate I. fig. 1) consists of converting the polygon into a series of re-entering angles en tenaille, flanked by casemated caponières, instead of the Bastion system, with its lines of defence.

These caponières (*c*, figs. 1, 3, 4, and 6, Plates I. and II.) are again flanked by casemated batteries of three stories, between the inner couvre-face (*s*) and the cavalier of the curtain (*m*).

The body of the place and the caponières are surrounded by counterguards (*b*, *b*), and the re-entering angle of these flanked by casemates (*g*, *g*). In front of these, again, ravelins (*c*, *c*) with casemated flanks (*d*, *d*) are placed, and externally the whole has a covert-way and glacis.

Although the couvre-face (*s*) and counterguards have thin ramparts of earth, they have, near the foot of the exterior slope, a loopholed escarp of two or three stories, as shewn in section, fig. 2.

Within the couvre-face (*s*), at each salient angle of the polygon, is placed an angular tower (Plates I. and II.), which has been much followed in the German System; and the fortress of Coblentz shews several of that construction. The tower is 40 feet in diameter, and four stories high, and its base forms a regular dodecagon, the salient angles having 60°, and the faces protect each other by a direct fire, (see figs. 7 and 8, Plate II.) The external walls are from 3 to 4 feet 6 inches thick, diminishing from 18 inches to 2 feet. The second and third stories have embrasures lined with brick ‡ for artillery; the parapet of the platform or upper story is also built of brick 10 feet thick, and the arch supporting it is 6 feet thick of brick. The artillery to be placed on traversing platforms of his own invention.

Montalembert calculates upon the construction of traverses, when wanted, on these towers, to avoid ricochet.

Plate II. figs. 7 and 8.

In the centre of the tower he constructs a circular réduit, of which the walls, 6 feet thick, are loopholed for ultimate or final defence: the tower has likewise excellent magazines, well secured with hydraulic cement. It is alleged that the approaches are seen from the three stories of the caponières (*c*), and those of the casemates and flanks (*g*, *g*), and of those noticed at *h*, and of the curtain (*k*), and of the casemated barracks (*n* and *w*), besides those from the couvre-faces and counterguards, and thus establish a fire from 430 pieces of artillery.

Nevertheless, works cannot see without being seen; hence the casemates (*d*, *d*) of the ravelin, those (*y*, *y*) and the loopholed escarps (*b*, *b* and *c*, *c*) would be immediately destroyed. Likewise the position of the caponière (*c*), which is liable to be hit on

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* From Le Baron P. Emile Maurice.

von Zastrow † M. A. ~~de Zostrew~~, author of a work called 'Permanent Fortification,' observes, that a complete revolution has been worked in the art of fortification by Montalembert.

‡ Although shot, with a velocity of 1500 feet per second, will penetrate eight times its diameter in brick, yet in masonry works brick is the best material, in similar circumstances, to prevent splinters.

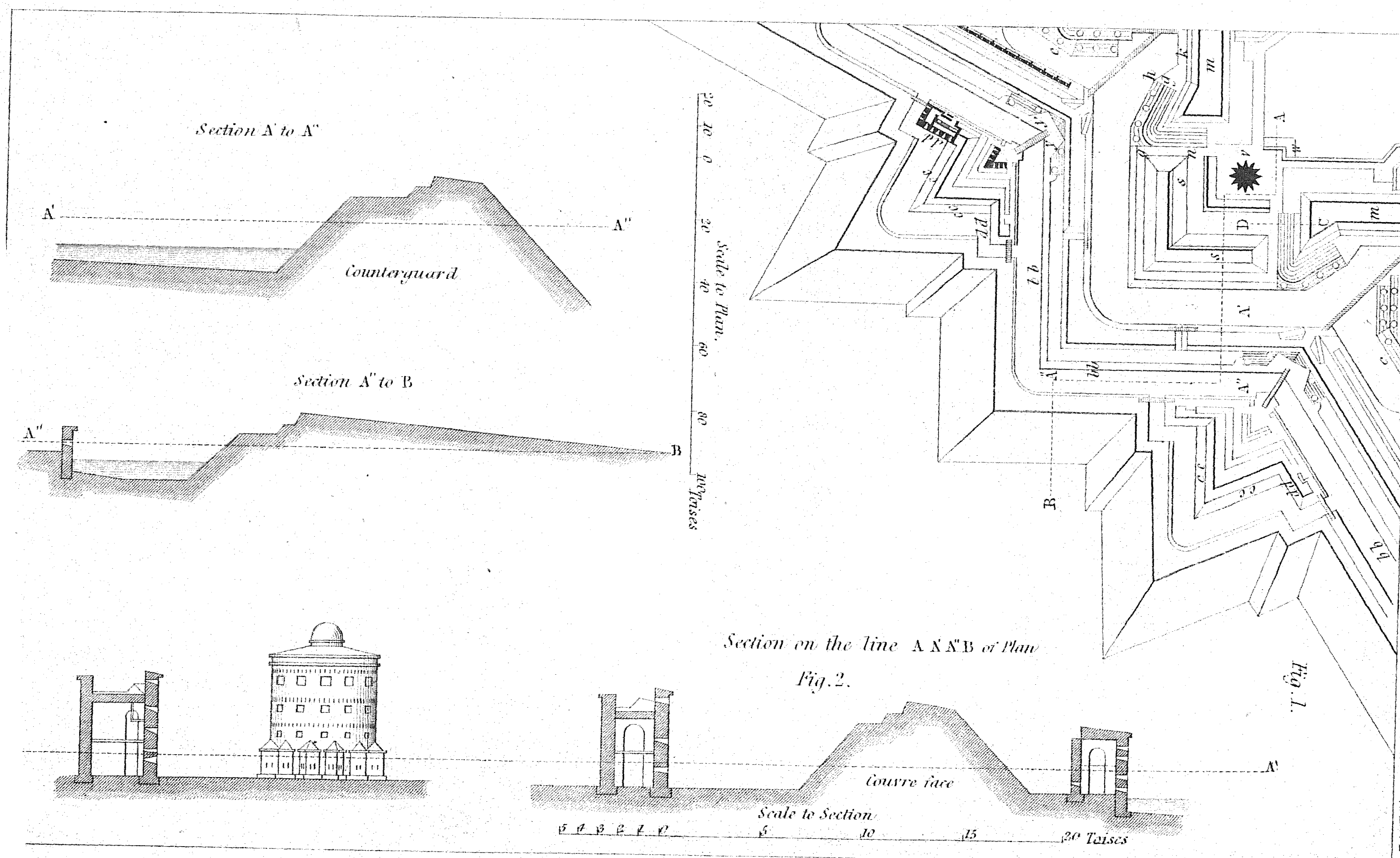

Section A' to A''
A'
A''
Counterguard
Section A'' to B
A''
B
Scale to Plan.
20 10 0 20 40 60 80 100 Toises
Section on the line A A'A''B of Plan
Fig. 2.
Couvre face
Scale to Section
5 4 3 2 1 0 5 10 15 20 Toises
Fig. 1.
A
D
A'
A''
B
m
c
s
bb
cc
dd

Fig. 3.

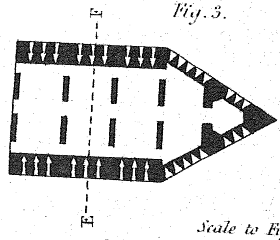
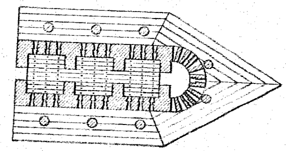


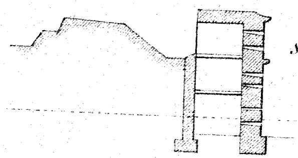
Fig. 4.



Scale to Figs 3 and 4

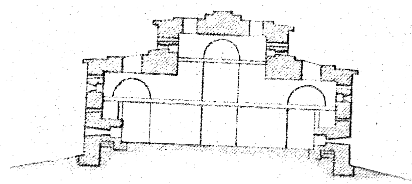
1 0 1 2 3 4 5 6 Toises

Fig. 5.



Section on the line C D
Plate 1

Fig. 6.
Section on the line E F



Scale to Figs 5 and 6

5 4 3 2 1 0 5 10 15 Toises

Fig. 7.

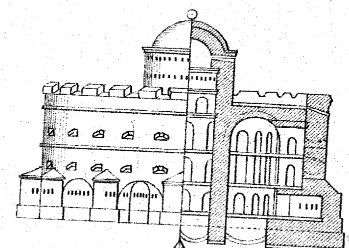
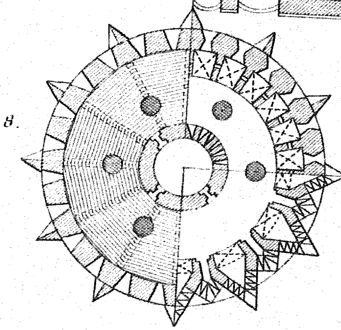


Fig. 8.



Scale to Figs 7 and 8.

5 4 3 2 1 0 5 10 15 20 Toises

each side, and would soon become untenable; when also the couvre-face (*s*), casemate (*v*), and defensible barrack (*w*), would be ruined by being open to the shot of the besiegers through the numerous embrasures. The military world must not therefore be imposed upon by the mass of masonry and double and treble tiers of embrasures of Montalembert's expensive system, all of which would be crumbled into ruins by heavy artillery at 800 yards distance.

CARNOT'S SYSTEM.

SECTION I.

"Le nouveau mode de défense consiste donc dans ce jeu alternatif des sorties et des feux verticaux; de manière que l'ennemi ne puisse éluder ceux-ci sans s'exposer à celles-là, ni se mettre en mesure contre les premières, sans se faire accabler par les autres."

De la Défense des Places Forts, par M. Carnot, 3rd edition.

But what is the effect of this vertical fire, which has not been appreciated, and never made the basis of defence, as proposed in this system of fortification? * (See Plate, Carnot's System.) It is to bring these means into play after the establishment of the third parallel, which it is supposed will be fixed about 50 toises from the salients of the ravelin; and as the usual bastion fronts are 180 toises, the space taken by the besiegers in advancing to the covert-way will be about 9000 square toises; but as it is probable that they may diverge a little to the right or to the left, the space may be considered 15,000 square toises.

Now this extent, it is fair to suppose, will be occupied by 3000 men, either employed in the siege operations, or as guards to the trenches, calculating the garrison at 4000 men: then, as each of the besiegers will cover one foot square, there will be 180 to every 5 toises square.

To oppose this force, let six 12-inch mortars be placed in each of the bastions and ravelin of the front attacked; that is, two on each capital, to fire on the zigzag approaches to the place; and as each mortar can throw 150 balls of 1lb., or 600 of ¼lb., the six can discharge 3600, which ought to destroy 20 men; and as 100 rounds can be fired per hour, 2000 men will be put hors de combat in 24 hours, or 20,000 in 10 days,—the probable period between the establishment of the third parallel and the opening of the breach.

Should, however, the besiegers attempt to secure themselves by blindages, the least sortie will throw them into confusion, without considering the immense quantity of timber necessary to protect themselves.

Hence the importance of vertical fire in the defence of places is demonstrated: 1st. By the impossibility, after the third parallel, to reserve any other fire. 2ndly. By the difficulty of reaching the besiegers in their trenches by any other means.

This description of defence, besides, is not reciprocal, and not available, as it has been before shewn, to the besiegers, who have no cover, whilst the besieged are secure in their casemates, constructed on purpose.

Plate III.—Figs. 4 and 5 of the Bastion System explain the manner in which it is proposed to organize vertical fire, in the existing systems, to be constructed in the capitals of the bastions and ravelins for 21 heavy mortars to each front, which arrangement does not interfere with the ordinary complement of artillery and musketry on the ramparts, which, when the besiegers obtain the ascendant, will be withdrawn, and the defence, as regards the artillery, will be left to the casemated batteries for vertical fire, for stones, grenades, or iron balls, according to the near approach to the covert-way.

* This observation is as applicable to 1847 as to 1810, when the system was proposed.—*Ed.*

SECTION II.—APPLICATION OF THIS PRINCIPLE TO A SPECIAL SYSTEM OF FORTIFICATION.

Plate, Carnot's System.

First, for Low Aquatic Ground (figs. 1 and 4).

As fortifications constructed on aquatic sites involve considerable expense, it is not possible but to admire the means adopted by Coehorn, with his limited resources, and the excellent principles inculcated by that celebrated Engineer.

The great difficulty, in similar circumstances, is to find materials sufficient for the ramparts and glacis, and for that reason it is proposed to dispense with the latter, however the security of the place requires that the enceinte should be complete and of the proper height against an assault. This enceinte will be merely a loopholed wall of two stories, as shewn in fig. 4, except at the re-entering angles, which will be casemated for artillery; and it will be perfectly hidden by the body of the place, on which it is necessary for the besiegers to establish their batteries to breach the wall. These (the loopholed wall and rampart in front) ought to suffice; but as it is necessary to communicate without by boats for offensive operations, a counterguard is placed parallel with the body of the place, also constructed of earth, shot-proof, yet so narrow that the besiegers have not space to lodge themselves on.

In proposing this system of defence, the bastion form is not adopted, as dead angles are of little importance with wet ditches; therefore, the angular shape is preferred, on account of its simplicity and economy.

The details of this trace (see figs. 1 and 4) give an inner wall, as already explained, without any rampart, forming a series of redans, of which the salients (*x x*) may be from 50 to 100 toises apart, according to the size of the polygon, the Plate representing a dodecagon. This wall, which surrounds the town, is built upon the natural soil to save expense, and is 6 feet thick and 24 feet in height, in arcades taken from the thickness of the wall, (see fig. 4.) At six toises in front of this wall is the interior slope of the body of the place; the latter is also 24 feet high and 18 toises wide, and leading from which are sally-ports to the tenaille, to cover the re-entering angle, and connect it with the place of arms on the counterscarp by an open earthen caponière. The width of the counterguard is similar to the tenaille, 12 toises; the wet ditches are all 6 feet deep, and the glacis is contre-pente. The re-entering angles of the inner wall are casemated, with terreplein and parapet of earth, on which may be placed 16-pounder guns. These casemates are not an essential part of the system; but as bomb-proofs are necesary for a good defence, these serve the purpose.

Secondly, the application of the System to High Ground.

It has been observed that the bastion form is with difficulty adapted to uneven ground, on account of the length of the fronts, and that the angular trace is better suited to the inequalities of a hilly country: the same system is therefore preferred as proposed for that which is low and wet, with some modifications which local circumstances require.

1st. To give a greater height to the escarp to avoid escalade; and 2ndly, to obtain a better command over the uneven ground without.

The details, as shewn in figs. 2 and 3, give the inner walls 36 feet in height and 6 feet in thickness. The construction of the body of the place is similar to that with the wet ditches, except at the foot of the exterior slope, where a loopholed wall, 18 feet high, is constructed, as likewise all round the tenaille, to prevent surprise, to which the nature of the system with dry ditches, without a covert-way, is liable.

Fig. 1. Carnot with wet Ditch

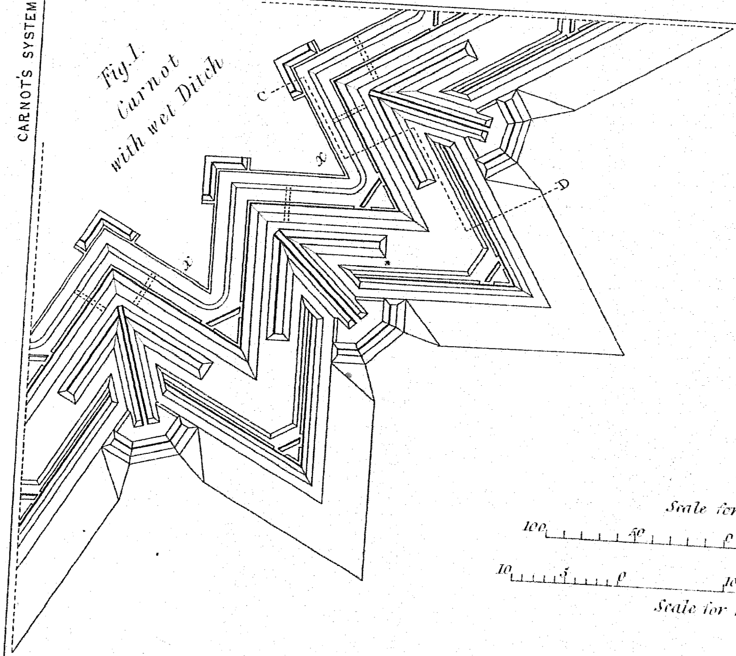
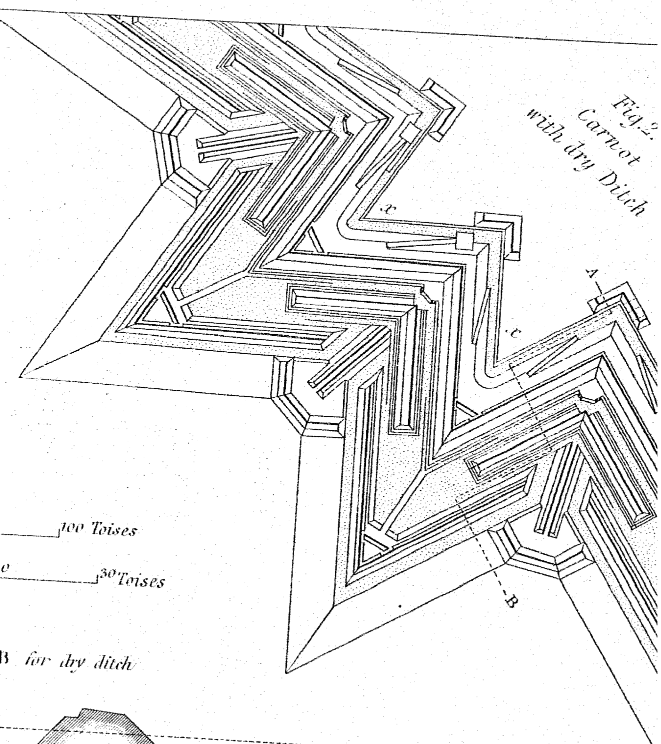
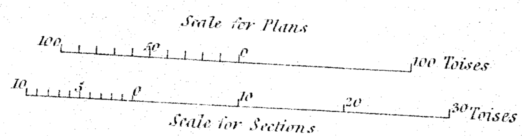


Fig. 2. Carnot with dry Ditch





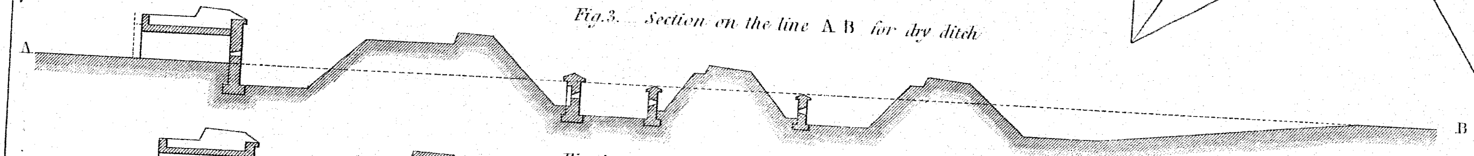


Fig. 3. Section on the line A B for dry ditch

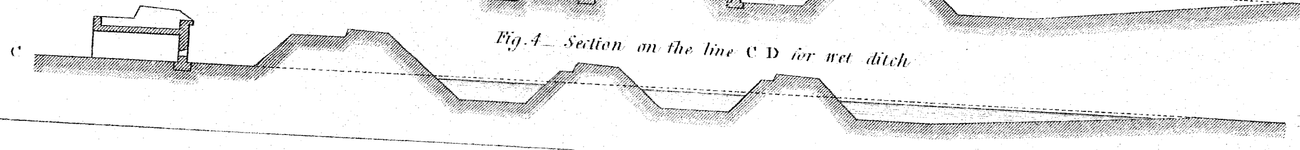


Fig. 4. Section on the line C D for wet ditch

ON THE MODERN SYSTEM OF PRUSSIAN OR GERMAN FORTIFICATION.

PRELIMINARY REMARKS BY THE TRANSLATOR.*

The new system of fortification, as carrying out throughout the whole extent of the German dominions, now claims our attention, (see Plates I. II. and III. figs. 1, 2, 3, 4, and 5, German System.)

The motives which led to the introduction of this new method may be briefly enumerated as follows, viz.

The inefficiency of the various Bastion systems employed, from Vauban and Cormontaigne, down to Bousmard and others, for a protracted defence, after the establishment of the third parallel.

The want of a free communication for troops within the works, for sorties, &c.

Also the inefficiency of the flanking fire of the various works under the old system.

Vauban, who was convinced by great experience that Bastion fortifications, which he himself had built, were not able to oppose a sufficiently durable resistance to a regular attack, and that in the latter period of the siege they even accelerated the besiegers' progress in overwhelming the garrison, applied himself, in his latter days, to the object of strengthening his fortifications; and he endeavoured to accomplish this by means of *isolating his bastions*, connecting them by an intrenchment, and also by masked flanks.

Bousmard, in order to prevent or render more difficult the enfilading the faces and flanks of the bastions, gives them a flat curve, and also supplies the flanks of the tenaille with casemated sheds for the guns, to strengthen and secure the command of the main ditch.

These and other expedients have been proposed by various masters of the science, but have been found so complicated and expensive, that they have rarely, if ever, been resorted to in practice, however good they may have been in theory.

In the attack, as established by Vauban, of fortified places, the works are carried on (under ordinary circumstances) from the first, second, and third parallel, irresistibly, to the establishment of counter and breaching batteries,—the passage of the ditch,—the storming and consequent surrender of the fortress. Under the new Prussian or German system this will no longer be the case: the attack will be carried on as usual to the third parallel, or as far as the foot of the glacis; but here will commence a hand to hand, and most destructive opposition, which will only cease with the capture of the last redoubt.

Before entering upon the details of the construction of the German System, we will take a cursory glance at its principal variations from the old and commonly received systems. First, then, we shall observe the increased length of the fronts or faces of polygons; these extend from 500 to 600 yards;—also the simplicity of the trace, which of itself diminishes expense.

Secondly, we shall remark the free communications for troops afforded by the works of the new system, as seen in Plates I. II. and III.

Thirdly, we shall notice the different system of flanking observed in it: this is usually done by means of *caponières*, which, projecting from the centre of fronts of fortification, command the ditches, in their full extent from the lower tier of guns; and the terreplein of the covert-way, with the crest of the glacis, from the upper tier; with the incalculable advantage of their powers of defence being un-

* Colonel Stavely, late of the Royal Engineers.

touched and uninjured to the latest period of the siege, when all the best efforts of the garrison will be called into play.

Large and powerful *redoubts* are an invariable accompaniment of the new system, in all its phases. These are of various construction, and depend much on the nature of the works. In small forts or advanced isolated works, they occupy the rear or gorge, not only as defensive barracks, commanding the interior or terreplein, but also as cavaliers, looking over the distant country and commanding the approaches: sometimes, as in the fronts of fortification, surrounding a large town, they act as caponières, and flank the faces, as in Plate III. fig. 5; in others, they are placed immediately in rear of the works as bomb-proof casernes, and also as cavaliers, thus affording secure shelter both from vertical and direct fire to the troops immediately on duty on the fronts attacked, and preserving them untouched and ready for the exertions required of them during the last periods of the siege.

By this brief exposition, it will be seen that the new system is not confined to any invariable rules, but adapts itself to ground and circumstances; and for this reason no single plan of a fortification will give a clear and adequate idea of the whole system.

We may also remark that there is a considerable difference between the *Prussian* and *Austrian* Systems, the former being employed generally in the North and West of Germany, and the latter in the Southern States.

It may be taken for granted, that the conventional dimensions of the details of works, as established by Vauban and Cormontaigne, are preserved; for as these authors only adopted them on the invariable rules observed in natural objects, and on the science of gunnery, as their basis,—they can only be changed by great improvements in the latter, as regards the range and calibre of cannon and musketry; and it is this, be it observed, which establishes in the new system the extent of the fronts,—the guns in the caponières having on each side a point blank range for grape and canister of 300 yards.

Thus far we have written, as forming preliminary observations to the present article, viz. 'A Description of the New German System of Fortification;' which object we think cannot be better effected than by giving here a translation of such portions of the work, published in Berlin, in March, 1844, by Major-General Brèze, Inspector of Fortifications, as are calculated to afford a clear general view of the subject, and without entering into minute details, which the limit of the article would not permit us to do. T. K. S.

"The spirit of modern tactics has been applied for some time to the Art of Fortification, and the object has been to compose fortresses of single independent works, capable of affording a lasting resistance; but which are to be mutually connected, according to circumstances, by intermediate lines, thus forming a net of works expressly adapted for a step by step struggle for the possession of the ground; and which is to be carried on as long as the last part of the last work is tenable.

"If this object could be completely realized, then the ideal of a fortification would be obtained, and that again would lead to the ideal of a defence, such as the struggle at Saragossa from house to house, and from wall to wall, has shewn to be practicable.

"When the fortifying of a piece of ground has been determined on by strategic principles, the Engineer chooses those points which, from their formation, must be considered as the most influential, and the best adapted to the consummation of the different military designs; also as the most necessary to be maintained.

"These points are made the main posts of the position. Casemated defensive barracks are constructed on them, in the form of *round towers*, or isolated *angular castella*, according as the range to be commanded from them may require the one or the other: they are built, according to circumstances, with two or three stories, and are furnished on the top with a gun-platform, sheltered by a parapet, which, in the manner of a cavalier, is to overlook and command the surrounding country.

"In this manner are obtained firm posts, which afford absolute safety against powerful enterprises, and oblige the enemy, who is moving towards them, to make a regular attack. The experience derived from Saragossa and Dantzig have already taught, on the one hand, how short and ineffective is the resistance of such works, if their walls are quite exposed to a direct fire from heavy guns; on the other hand, what a lasting and effective defence they are capable of, if they are quite sheltered from the fire from without: it becomes necessary therefore, to shelter our towers and defensive barracks (casernes défensifs) as much as possible from the effect of a direct fire, by means of lines of walls or ramparts, thrown out in front.

"If the attack by artillery is practicable on all sides, then the towers must be sheltered all round; but if several of these works form together a position, having in its rear a large and independent main-work, then the construction of protecting lines becomes necessary only on those sides on which the enemy's advance with batteries and approaches is to be feared.

"That part of these works, then, which lies opposite to the main-work in its rear, may be considered as the gorge, and as such is only surrounded with a wall, to secure it against a coup de main, and to enable the main-work to throw open and sweep the interior of it, should the enemy succeed in establishing himself there. The defensive barracks or castella, protected from without, as high as the cordon of its walls, by the rampart thrown up in front, forms now the *réduit* of the whole work, and its height is so regulated, that it may from its lower story sweep the terreplein of the work with musketry; and from its upper story, which is adapted for artillery, it may command the rampart, and attack, with a superior fire, the enemy's lodgement there, should he effect any; also, that it may fire over the rampart in front, on to the field of attack, from the gun-platforms lying over the casemates, which, in the manner of a cavalier, command the country.

"Besides, the covered story for guns is well adapted for placing howitzers to fire incessantly into the works of attack, approaching from the extreme edge of the ditch.

"The line of the rampart, surrounding the *réduit*, is placed as becomes necessary for sweeping the ground in front, and for flanking co-operation of the adjoining works.

"The escarp is generally revetted with masonry, and, in very exposed parts, constructed with a 'revêtement en décharge.'

"The ditch is flanked by masked batteries, belonging to the work itself, which are constructed either in the independent *caponières* of the ditch, or even under the counterscarp.

"The latter is supplied as a part of the system, and the covered-way, opposite the salient angle of the work, with blockhouses.

"This, in general, is the type of our independent works, as is also shewn in Plate I. The perfect safety of these works from being stormed is not to be doubted, and is secured in the last ~~resort~~ by the bomb-proof *réduit*, occupying the interior of them.

"The broad intervals between the single forts,—the spacious esplanades enclosed in them, and the far extending co-operation of the guns of the works, which protect

offensive movements and cover retreats,—favor, in an extraordinary degree, the free movements of large or small bodies of troops, in view of the enemy, either in advancing them or retiring them; also enterprises of an effective garrison against a progressive regular attack will find energetic support and flank defence in a field of combat so well prepared.

"The step by step defence of and possession of the ground, may, by this method of fortifying, be rendered durable; which could never be the case by the older systems. Certainly the small extension of the lines of rampart does not enable the single works to oppose to the enemy's artillery an equal number of guns, which might be sufficiently numerous to enable them to engage in a short warfare, carried on by batteries; but this must be carefully avoided, in the defence of fortresses, unless you can rely on undoubted superiority; and then, by a careful application of the guns, you will succeed by keeping some ready, close under the 'bonnets' or traverses, to preserve them intact by means of wood-work and earth, in order to produce them at the right moment, when, by a few rapid discharges, they may bring the head of the sap to a stand-still, disturb the construction of a battery, or take advantage of any faults the enemy may commit; and though the use of the guns on the rampart be limited according to circumstances, yet the artillery will, by means of mortars and howitzers in its *numerous* and *covered positions*, be able to display an activity so much the more certain and uninterrupted, as its position is not materially endangered either by direct or vertical fire.

"In the next place it must be considered, that in the progress of a regular attack, in *each separate work*, every process incident to the siege of a fortress must be gone through; after which the assailants will be checked at each redoubt, which, of course, must be gradually overpowered by artillery, or by mines.

"This tedious and sanguinary operation must be repeated as often as there are single works, which, by their co-operation, render their capture necessary.

"Let us, for example, take a fortification such as is represented in Plate I. (German System), and it will be seen here that all four works, whose mutual strong flank defences and supports (as far as they are affected by firing from covered positions) cannot be destroyed by batteries in the parallels, must be taken one after the other; and the enemy cannot consider himself in possession of the ground, or of the avenue leading to the bridge, until he have taken the réduit of the fourth and last work.

"Now, if we compare this new system of fortification with the older system of bastions, and consider the means of resistance, as well as the quantity of materials required for the construction and armament of each of them, we may obtain something like the following result.

"If the distance between each independent work be taken at from 700 to 800 paces, then a line of rampart (on the Bastion system), which would surround and protect an equal extent of ground, would require a circumvallation of seven fronts of from 80 to 90 rods* in length. The expense of building this could not be taken under 1,800,000 rix-dollars, that is, giving it revetted escarps of the usual height—also ravelins and a covert-way over the counterscarp, and constructing the necessary buildings (only such as are commonly used) in the interior of the work, for keeping stores and provisions in.

"On the other hand, the cost of constructing the four independent works, whose covered defensive spaces afford at the same time bomb-proof shelter for troops,

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* A rod is equal to 12 feet 4½ inches.

ammunition, stores, and provisions, would not from experience exceed 1,500,000 rix-dollars.

"The fortification on the Bastion system, would, from its extent, require a garrison of at least 3000 men, with 120 to 130 guns and appurtenances, and provisions in proportion; whereas the whole four independent forts might be ably defended by 1500 men and from 80 to 90 pieces of cannon.

"The former would have to surrender, on a lodgement being accomplished on the glacis, and a breach made and stormed, *while the greater part of its works never took part in the struggle;* whereas the four independent forts cannot be considered as overcome, until the tedious operation of taking the works, around each réduit, is four times repeated: and then each réduit must be taken,—consequently, not until all means of defence have been entirely destroyed; added to which, they can (with a much less expenditure of money and materials for their construction, armament, and defence,) afford, when compared with the 'Bastion enceinte,' a resistance three and four times as great, quite independent of the incalculable advantage they possess over the latter, in having bomb-proof places of shelter for the men and guns in those parts where they are wanted,—thereby causing a great saving, and obtaining a longer use of, the forces and materials used in the defence,—affording rest for that portion of the troops which is not actually engaged, but kept near at hand as a reserve,—and lastly, in the confidence gained by the garrison from the knowledge of the great strength of their works. All these advantages cannot fail in producing a good moral effect on the troops: besides, in an independent work of this description, a daily relief of the garrison is not required; but its defence would be permanently intrusted to one division, which would take up its quarters in it, arrange the different garrison duties, and learn to consider the work as its home, the defence of which would be a point of honour, and the men would join their own existence to the last heap of ruins.

"The other works, not immediately attacked, are required to render every assistance to the post that is engaged, by means of their guns, and also by offensive movements, checking the progress of the works of attack by frequent sorties; thereby keeping up the communication with the garrison that is attacked, in order to supply it with the different articles it ~~wants they~~ may require.

"No work must be abandoned until all means of defence have been exhausted. Now if the tenor of the foregoing remarks be summed up, we shall obtain the following maxims, which are observed by us (*i. e.* the Prussians) in the organization of our new fortresses, consisting of *isolated works.*

"Each independent work opposed to a regular attack receives covered as well as open gun-platforms, for the different kinds of ordnance, in their appropriate positions. The ditches are flanked by covered spaces, in order that the men who are constantly on duty here may be sheltered from a coup de main, hand-grenades, and the weather. This flank defence of the ditch, corresponding to the isolation of the work, is connected with it, and also with the redoubt, if possible, by means of covered communications; but it is not intrusted to an adjacent work, that is separated from it. The masonry, as well as the covered batteries, must not be exposed to direct fire from the parallels.

"Each work must have a bomb-proof place of resort for those men who are off duty. This place, and the magazine for several days' provisions, are both connected with the principal redoubt, lying in the interior of the work, and sheltered from the fire from without.

"This redoubt (if peculiar circumstances do not prevent it) is pushed into the gorge of the work, to gain thereby a more spacious court in front of it; to obtain a sufficiently

safe position for the gorge and gateways; to enable the works lying behind the redoubt to observe its condition when engaged in close combat, and render assistance accordingly; and, finally, to allow those of its covered guns which project from the branches of the redoubt, out of the wall of the gorge, to take in reverse or flank from behind the profiles of the gorge, the enemy's lodgements on the glacis of the adjoining works. This is shewn in Plate I.

"By means of this co-operation of the redoubts, the relative strength of the independent works, standing with mutual reference to one another, is greatly increased, and their possession, which is only to be accomplished by a great sacrifice of time and forces on the part of the besiegers, is made a necessity to them.

"The covered-way, with its blockhouses and undermined glacis, forms a first strong line, which can only be taken possession of by means of *sapping and mining.*

"The rampart, with its covered flank defences of the ditch, forms a second and stronger position behind the first; and to pass which, counter and breaching batteries must be erected.

"The redoubt, in the interior of the work, as a 'centre and commanding cavalier,' forms, lastly, the strongest part of the whole, and is generally only to be overcome by mining, provided the nature of the ground be adapted for it.

"By reference to the foregoing statement, we shall come to the conclusion, that thus one of the main objects of the art of fortification is accomplished; viz. that the strength of each part of the whole of this system, rampart, réduit, or caponière, whether acting as flank or front, is, during the progress of the siege, fully developed, so that no one of them acts only a passing or ineffectual part, or falls at its close unscathed into the hands of the enemy.

"The Fort of Kaiser Franz,* at Coblentz, situated between the ~~right~~ left bank of the Moselle and left bank of the Rhine, has been built with the same views that dictated the formation of a fortification composed of single independent works, as represented in fig. 2, Plate II. This fort commands the passage over the massive bridge of the Moselle: it has the Moselle front of the town as a basis behind it, and the west or Rhine front of Ehrenbreitstein on its right: both fronts command the interior of this large tête de pont, which, from its construction, is, simple as it may appear, in a high degree capable of defence, and, from its means of affording cover, is as comprehensive as it is conducive to the movement of troops: above all, the independence of the principal part of the fortification, the systems of réduit and retrenchment, *first used in the new works at Coblentz,* stand out prominently and distinctly, and have since been used by us (the Prussians) as well in the large new fortifications of Cologne, Posen, and Thorn, as also in enclosing and strengthening other fortified places, such as Saar-louis, Julich, Wesel, Minden, Erfurt, Spandau, Kustrin, Glogau, and others.

"In other States also, the system of independent works is becoming the prevailing one; as for instance, in the new outworks of Mayence,—the tête de pont at Ingolstadt,—at Gemersheim,—in the towers of the intrenched camp of Linz, and in many other newly projected fortifications.† With regard to the latter, the general principle seems to be, that a massive tower or bomb-proof redoubt of a different form should be sheltered from a direct fire from without, by means of an earthen-work thrown up in front; but this cover, on both sides, is only to extend back so far as to enable the redoubt, behind its profiles, to give a strong flank defence to the adjoining work. *Vide* fig. 3 in the Plate II.

"*Great towns* lie mostly on rivers,—those arteries and defensive lines of the interior

* Emperor Alexander.

† Austrian.

of the country, on which its strategic defence mainly depends. They are generally built where the principal great roads cross a river: they form the conflux of the traffic and prosperity of the province: they contain the money and the means wherewith to carry on the war; and it is, therefore, as indispensable to preserve these treasures for one's own use, as to keep them from the hands of the enemy.

"Owing to this, the fortification of large towns has always been a main object with *us;* and with reference to the past and present, we have only to look at Magdeburg, Erfurt, Stettin, Dantzig, Cologne, Coblentz, Posen, and Konigsberg.

"The fortification of such large places, however, presents generally many difficulties, not only on account of the formation the ground may have near the bank of the river, but also on account of the considerable expense incurred by the great extent of the enceintes; and it has therefore often been inquired, whether it would not be advisable (from the various advantages presented by the application of isolated independent works, both with regard to their capability of offering a long resistance, and also of favoring, in a high degree, all movements of troops,) to abandon entirely, in the new fortifications, the connected circumvallation of large places of arms and towns, and place in their stead only a chain of strong detached works, but which should be near enough to one another to prevent, by their mutual co-operation and cross fire, the enemy's endeavours to push in between them.

"This may do in theory, but practice will decidedly condemn it.

"The Maximilian towers at Linz are only expressly intended for forming an intrenched camp, which is to give an army, in case of its being defeated on the Upper Danube, a safe position on both sides of the river, and then to enable it, according to circumstances, to act again on the offensive, should the enemy advance; also to assist the line of operations.

"Linz can therefore in nowise be considered as a fortress, though *unforeseen circumstances might* require that the town, with its surrounding towers, should for a time be intrusted with a garrison of several thousand men, to prevent so important a place from falling into the hands of the enemy without a further struggle. According to report, it is intended, in the event of such a case, to close the intermediate ground between the towers with field fortifications and palisades, and to subject their re-entering lines to the flank defence of the towers. But will the garrison ever be strong enough to complete this enclosing operation in right time, and to a sufficient degree? May not then the reproach be justly made, that during a peace, when there was no want of time and means, they let slip such a fair opportunity of giving the whole position a solid basis by a fortification of this description?

"And will these works, constructed in a hurry, be ever sufficiently strong to secure the town and its magazines from being suddenly broken into at night by a force perhaps ten times as great as that of the garrison?

"Even for a strong garrison, the task of defending for a long time a fortification consisting only of isolated works is always a difficult one: the attack always commands a force sufficient to insure reliefs and rest; in the defence they must be constantly on the 'qui vive.'

"For these and other reasons it therefore appears *imperative* to enclose the principal inner parts of a fortification (the centre of the whole) with a connected circumvallation, which is besides indispensable on account of the shelter required from a direct fire from without.

"Accordingly, outside the enceinte (in great towns) there must be constructed, according to the formation of the ground, detached forts or strong lunettes, thrown out in an advance of from 500 to 800 paces, in order to command all the windings of the ground in front, and to restrict the enemy's attack to a distance of at least

twice the width between the two parallels from the main fortification; also to afford powerful support to an effective garrison, which, instead of waiting passively, is ever on the look-out for opportunities of making advantageous sorties.

"This outer strengthening must be applied particularly to the fronts that are accessible to an approach, and those works must therefore be especially considered which flank the field of attack, but which are secured by the natural obstacles of the ground from a direct attack by means of sap.

"If the interior of these works be provided with bomb-proof redoubts in the gorge, which are adapted for a flank defence such as we have just spoken of, and which cannot be destroyed by the enemy's silencing batteries, then the fronts, which were formerly accessible, may thereby be rendered nearly inaccessible.

"The object of the connected enceinte of the centre is more of a defensive, and that of the system of advanced lunettes more of an offensive nature; so that by uniting the two, all essential interests, both with regard to the defence and also all great operations of the befriending army relating to the fortress, might be realized.

"In Plate III. fig. 5, is represented, though only on a small scale, the fortification of a great 'place d'armes,' surrounded by detached forts and lunettes, and is somewhat similar to the manner in which Cologne is fortified. The ground is level and approachable every where, on account of which the division of the advanced works has been pretty regular. From whatever side the place may be attacked, the successive capture of most of the detached works will be necessary before the besiegers can advance against the main-work itself; that is, provided in an attack directed against the upper or lower side of that part of the fortress adjoining the river, in order to avoid coming in contact with the branch-works on the right bank, the besiegers prefer attacking the more central fronts, in which case they would have to take the works (tinted) one after the other, to secure their approaches from being surrounded and enfiladed. And then the lunettes yet remaining to the fortress would, by increasing the length of front that is attacked, still give an unusual increase in strength to the fortification, and conduce much to the effect of sorties directed against both wings of the attack.

"If at the defence of Kolberg a single outwork, and of small extent, could delay the attack for weeks, how much more may we not expect from an energetic maintenance of a field of combat so well prepared as that we have just considered, and in which, only as a preliminary to attacking the strongest part of the fortress, seven independent sieges must take place in all their stages, and during which a great quantity of material must necessarily have been consumed by the besiegers; so that perhaps the probability of seeing their attacking operations arrested is not very distant; and, at any rate, the attack of the principal enceinte can then only be carried on with reduced forces and a confidence much diminished, to the evident advantage of the besieged.

"This consideration has further led to the question,—whether it would not be sufficient to protect the inner space of the fortified ground—the town and the military establishments in it—only against a coup de main, by enclosing it with a wall simply loopholed and flanked by small caponières, thus throwing the real strength of the defence entirely on to the chain of advanced detached works, and increasing, as much as possible, their capability of resistance, by employing all those means which, in the simple construction of the inner enceinte, were not made use of. This proposition, also, must certainly be condemned; for even if you can give the advanced works a somewhat greater absolute strength, by increasing their extension, by giving them more covered batteries, by increasing the height of their walls, and giving them altogether an opportunity of developing greater forces,—yet, on the whole, no much

more favorable result will be obtained than was to be expected from the other construction and disposition of the works, even without increasing their strength in the manner we have shewn; for the counterscarp, the rampart with its flank defences, and the redoubt, will still have to be overcome, one by one, by means of sapping, artillery, and mines.

"Consequently, in strengthening single outposts at the expense of the principal enceinte lying behind them, on the one hand, all the benefit that was to be expected might not be obtained; and on the other hand, it might produce this evil consequence, that after the taking of a few forts, the simple line of walls, only intended for a defence against a coup de main, would be breached in a few days by heavy artillery, and the duration of the siege would thereby lose twice as much time as may have been gained in the defence of the outposts.

"Neither would it be justified by tactics; as if, for instance, an army acting on the defensive were to employ the greater number of its men in the occupation and defence of the villages, farm-houses, and hedges, lying in front of its position, and were to keep only a small reserve in its centre, which would not be strong enough to defend it in case a village were lost, and the enemy were to push on with an overwhelming force, and endeavour to break through the position.

"The main position, then, should always be strong enough to be able to maintain a siege with effect, even after the advanced outworks have been destroyed. *And the defence should gain in energy in proportion as that of the besiegers begins to slacken.*

"The principal enceinte should therefore be the strongest part of the position, unless particular circumstances in the formation of the ground render a deviation necessary.

"The question now arises, how the necessary independence of the different parts is to be applied to the formation of '*enclosed principal enceintes.*'

"This is to be effected by the most important points in the ground, which are to form the enceinte of the main position, being supplied with 'strong independent works, and connected by simple lines,' but which are to receive powerful flank defence from the redoubts, or from the covered batteries in the detached works: in fig. 4, Plate III., is represented a fort, such as has been actually constructed, and which will be sufficient to explain what has been said.

"The casemated principal redoubt of the fort, consisting of large defensive barracks and magazines, fully commands the interior space of the work, by means of its covered and open batteries. It overlooks every part of the enceinte in front: it stands in safe and immediate connection with the arrangements of the fortress for inundation, and also with the detached works,—forming thus a compact whole, which must be taken by a siege, if the enemy wishes to have unlimited possession of the whole position.

"The road leading to the attack of the redoubt is by the enceinte of the fort lying in front of it.

"The principal parts of which the latter consists are the seven casemated redoubts, marked black in the plan, and which constitute the main points of the position, and as such command the intermediate lines of communication, sweeping them both outside and inside.

"A fortification so constructed has this great advantage, that it can, in case of need, be maintained against superior numbers by a small force, which is then concentrated in the detached works. From the position of the redoubts with regard to the two straight faces of the fort, and which adjoin the principal one, it is immediately seen what great support they can give the latter by their flank fire; and it may be supposed that the greater half of the outer fortification, with its redoubts and flanks,

must be laid in ruins before the crowning of the glacis of the principal redoubt can be effected.

"The enceinte of which fig. 2, Plate II., represents a part, is organized entirely on similar principles.

"The principal redoubts, with their counterguards thrown out in front of them, and forming a bastion, are here the detached works, which occupy the principal points in a distance of from 700 to 800 paces of each other, and are connected by means of lines of retrenchment.

"This is the type of a fortification, such as will be applied in the intended circumvallation of several large 'places of arms,' and some of which are now in course of construction, but only to those fronts subject to a regular attack. In this polygonal fortification the fronts receive a length of about 150 rods, or 620 yards, nearly, but in which the line of defence will not, as the flanking of the connecting lines proceeds from the redoubts in the centre, be longer than 75 rods, or 350 paces, and are consequently adapted for the use of case-shot as well as musketry: with seven such fronts, the same space might be enclosed as would be included in the dodecagonal bastion, consisting of polygonal sides, only 90 rods long; whereby is obtained (independent of the disadvantage the latter has, in not being able to afford sufficient defence to its lines,) this important consideration, that the heptagon with large fronts (including the sweeping of the ditches in front of the counterguard of the redoubt) requires altogether only twenty-eight flank defences, while the dodecagon with its bastions requires forty-eight (including its ravelins), and giving each only two pieces of artillery, shews a greater expenditure by forty guns, with men to serve them.

"In the heptagon, with large fronts, this increase can either be dispensed with, or else it can be applied to the strengthening of single flanks.

"The redoubt in the centre of the front, and which can be safely connected with the two caponières of the ditches of its counterguard, unites in itself all the flank defences of the front,—sweeps, commands, and overlooks all its lines, both within and without,—affords, besides, covered places of accommodation for the men and stores,—and constitutes thus a separate strong redoubt, or citadel, on every front.

"Owing to the deep position of the flanking batteries, there are no places in the ditches which cannot be seen.

"Troops, with every description of arms, can be marched in sections along each front by two roads (as indicated in fig. 2, Plate II.); and these lead besides through the safely situated gates (at *a* and *b*) to the right and left of the redoubt into the main ditch,—from this convenient *appareil*, into the re-entering 'places of arms' of the covered-way, and from them again through the sally-port, on to the glacis.

"Eight columns can thus 'débouche,' at the same time, on the four adjoining fronts (without regard to any large gates that may exist), by which means any movement of troops can be effected, either for extensive operations, or for the purpose of a vigorous defence.

"Cavaliers, or 'casernes défensifs', are sometimes employed immediately in the rear of each front, which secure shelter for the troops immediately engaged in the defence of the fronts attacked,—as at Ingolstadt. *Vide* fig. 2, Plate II.

"Further, it will be seen, that the lines of the body of the place, which are constructed in as simple a manner as possible, are quite sheltered from enfilade; and that by extending them, sufficient room is gained, to allow of the guns being moved at different periods of the siege.

"The ~~length of the~~ faces of the counterguards may be very effectually covered by

means of ~~*concave*~~ *traverses*,* which may be placed in the head of these works, in the direction of the capitals, at H, in fig. 2. Such concave traverses are situated in the masonry, and are quite sheltered from without: they project above the line of fire of the work only by a parapet 4 feet high; so that seen from the outside, they look merely like common traverses. Their vault (or casemate, or gallery) under the rampart, presents a safe shelter for the men, and the upper part of them, lying on the rampart, will accommodate several heavy howitzers, or short 24-pounders, which, being completely sheltered, can fire over the parapet to the right and left, on to the ground of attack. As soon as the attack merges into the last period, and proceeds from the third parallel to the glacis of the counterguard, in order to effect lodgement there for the construction of counter and breaching batteries,—and when the attacking batteries are, from the position of the parallels and approaches, very much hindered from developing their full activity,—then the guns of the fortress take up the war again, with increased effect, as from 10 to 12 pieces of ordnance commence their fire now, quite unexpectedly, from the covered positions in each of the three or four main-works, overlooking the field of attack. Their position is better shewn by the ~~line~~ H R, fig. 2: they stand sheltered partly in the concave traverses in the salients of the counterguard, partly in the two stories of the redoubt, which are adapted for artillery, and of which the upper one lies high enough to sweep, by direct fire, the slopes of the glacis of the adjoining salients, as is indicated by lines of fire.

"The enemy's lodgements on the crest of the glacis are thus subjected to a flank and reverse fire from a position completely sheltered by the wall of the counterguard, which he will find great difficulty in counteracting. But if, notwithstanding these difficulties, the besiegers did succeed in erecting counter-batteries, and were also determined, in spite of the flank and reverse fire which cannot be silenced, to destroy the flank defences of the front, they would then be opposed to a superiority of twice their number of guns, half of which are situated in covered positions in the caponières of the ditches, or in the casemated flanks. Therefore it is hardly possible that they should succeed in their object by the use of artillery alone: a lodgement on the salient of the wall of the counterguard would better be effected by mining, which is a much slower process, and is so liable to be counteracted by a well prepared garrison. But suppose it to be accomplished; then, from this confined basis, ('where the ruins of the concave traverse that is destroyed hardly allow of a narrow obstruction being thrown up, and which is every moment liable to be blown up by countermines,') the attack must be directed against the very strongest part of the front,—against the redoubt itself with its superior fire; also against that part of the body of the place (haupt-wall) that adjoins the redoubt, and which is as yet entire.

"And if, even after this, the redoubt should be taken, the enemy will only be in possession of this single work.

"Therefore in this system of fortification, to end the whole siege by one blow (as could be done under the Bastion system) is utterly impossible.

"The garrison retains possession of all the other detached works whose redoubts can each maintain a separate siege, and stand in safe and intimate connection with each other; and it can therefore, 'by means of these small citadels, which command those streets and parts of the town which are near them,' carry on the defence to the very last.

"These are the general principles which characterize our new fortifications,—these the objects which determine their disposition, and which were suggested by Vauban

* 'Hohltraversen.'

and Sorwigai,—better understood by Rimpler,—were defined by Montalembert,—and lastly, confirmed by experience in warfare, as being the desired ~~attainments~~. results

"The motives of the new fortification are principally to remedy the evident defects in the 'System of Bastions,' which have been obviated by the introduction of independent and detached works, also of covered batteries, which cannot be destroyed from without,—of bomb-proof places for the troops in the works themselves,—and also in those positions where they are required for the defence,—by the construction of advanced and detached outposts, and lastly, by establishing practicable and safe communications for all movements of troops.

"If these principles have been the leading ones, in the newly constructed works of fortification, still there has been no *fixed system* observed by us.

"An incalculable number of places have been systematically constructed with the *same trace and profile,* and supplied with the same outworks, without regard as to whether any part of them be unapproachable ground, and was liable to a regular attack or not.

"What a saving might here have been effected, or how other parts might have been strengthened, without additional expense, if the unapproachable fronts had been merely secured against a coup de main, and the means thereby ~~spared~~ saved had been applied to the fronts that were liable to be attacked, or to the advanced outposts!

"Brèze,
"General Major and Engineer Inspector."

OBSERVATIONS ON THE RELATIVE AND POSITIVE VALUE OF THE VARIOUS SYSTEMS OF FORTIFICATION.

In offering remarks on the several systems described in the preceding pages, and their relative and positive value, it is proposed to consider the principles on which permanent fortification should be constructed.

1. *As elements for defence,* which may be divided into active and passive elements:

The former comprising a sufficient garrison and facilities for sorties, and communications from one work to another:

The latter combining an enceinte secure from escalade, at the same time well covered from without from direct fire, with a sufficiency of bomb-proof from vertical fire:

Finally, the resources to stand an assault when the breaches are made, either by an inner line or permanent intrenched inner work.

These elements of defence, in a perfect fortress, may be expressed thus—

$$\frac{f s\ \sqrt{a d v r}}{e}=x,$$

fs denoting the active elements of force of garrison, and means for sorties; and a, d, v, r, the passive ones—of the place being free from *assault*, *direct* and *vertical* fire, and *final resistance*,—divided by the *expense.*

2. *As elements of attack,* which the defensive principles are calculated to resist, as far as human ingenuity can suggest, exclusive of countermines, which have no particular reference to systems—being applicable to all with dry ditches. These should be based upon one universal system, as perfected by Vauban, by embracing the weakest fronts, or those most eligible for attack, at the prescribed distance

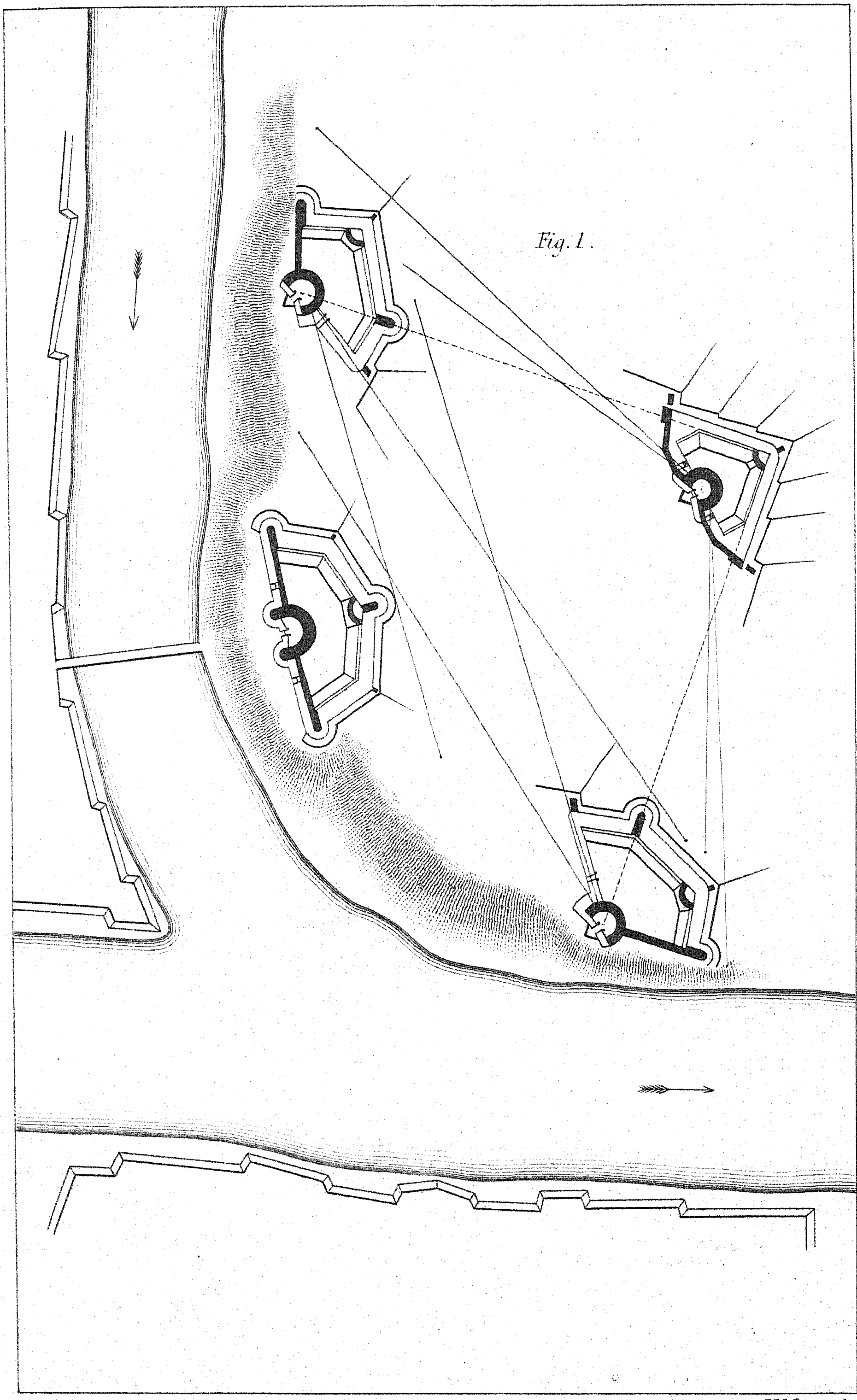


Fig. 1.

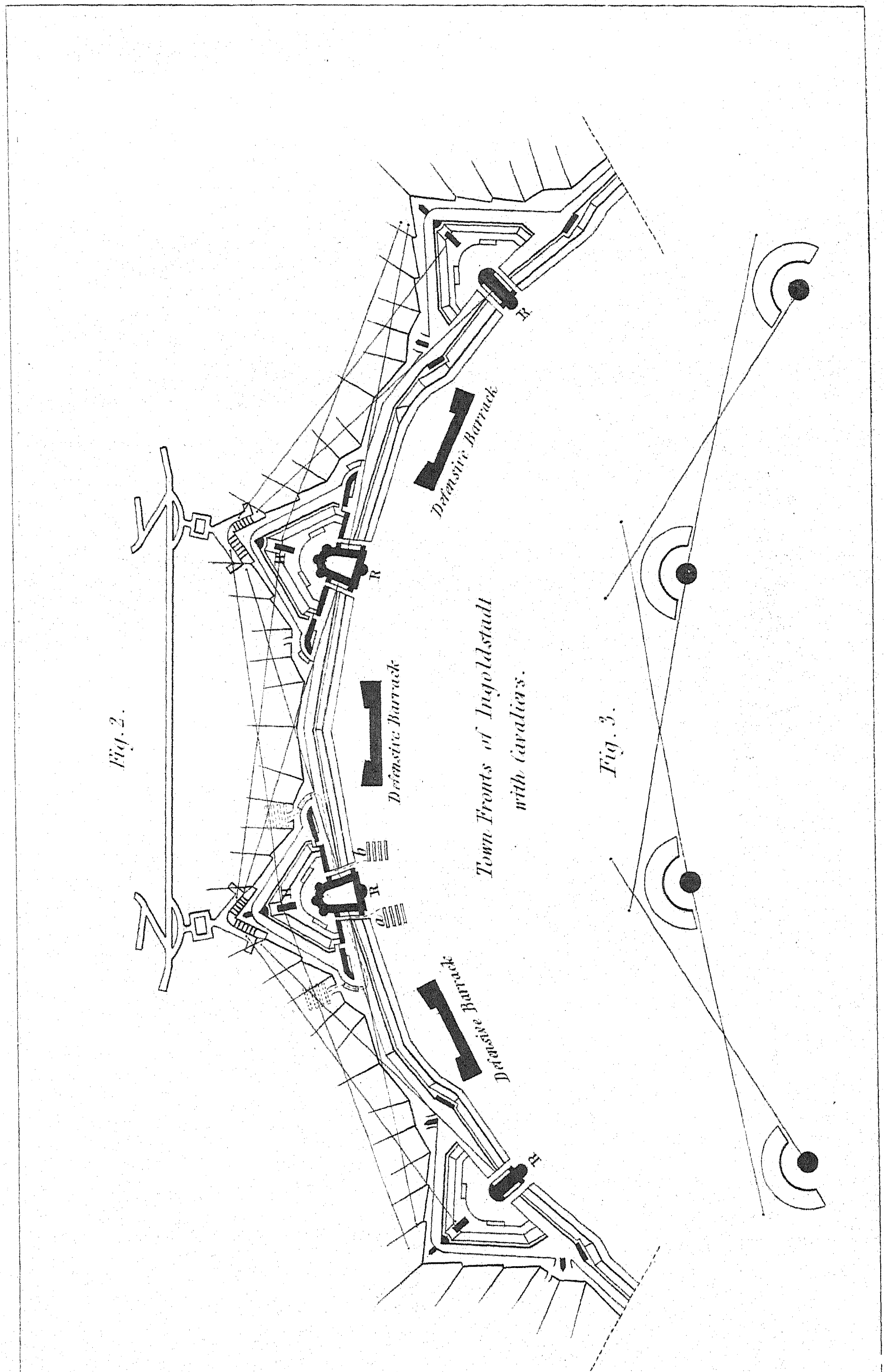


Fig. 2.

Town Fronts of Ingoldstadt with Cavaliers.

Fig. 3.

Fig. 4.

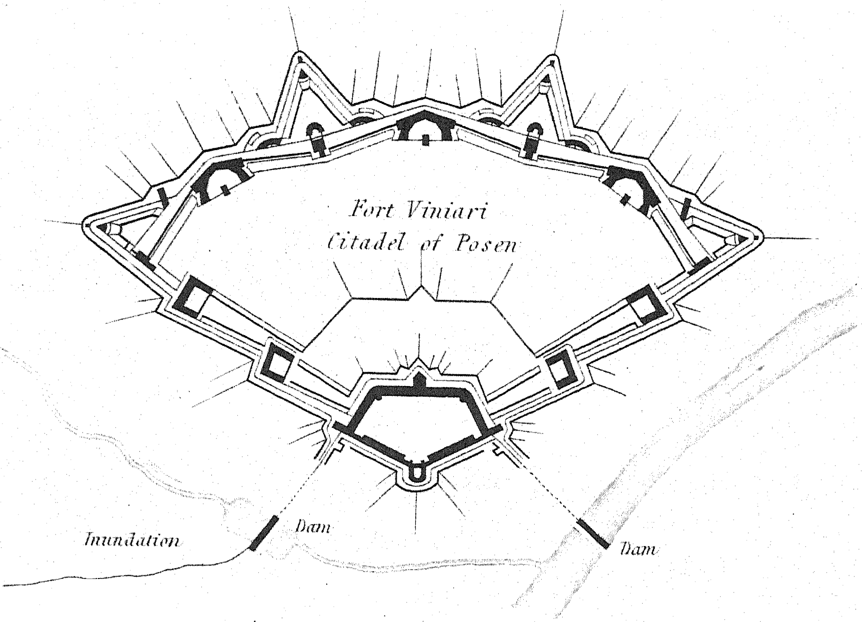
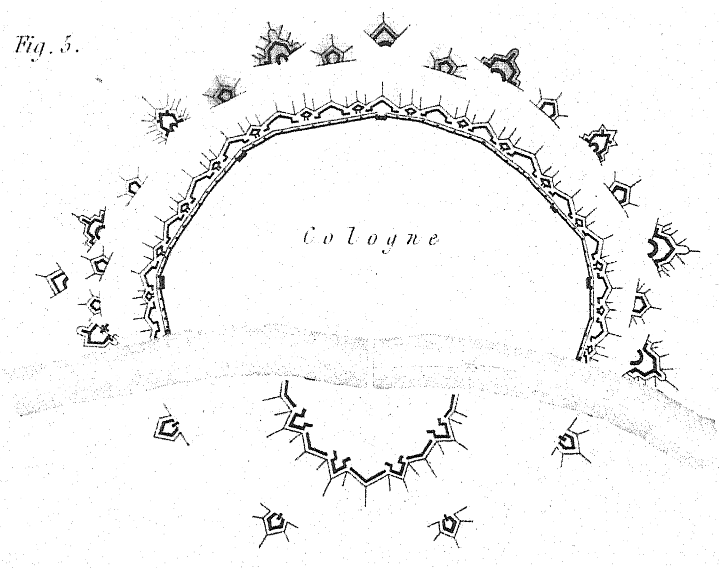


Fig. 5.



from the fortress, enfilading all the works open to ricochet, and destroying by direct fire every part exposed above the crest of the glacis. Under these operations, zigzag to another parallel line for the establishment of the vertical fire, and under this concentrated attack of artillery, which may consist of 50 to 200 pieces of ordnance, according to the strength of the place, the crest of the glacis is approached by sap, or by sapping and mining.

But fortresses may possess elements of defence irrespective of expense, as may be seen in that of Chasseloup and Bousmard, and in some of the German and Montalembert systems: and as in the latter an excess of bomb-proof cover has been given at a vast increase of cost,—for by a rule we have established, founded on experience, as explained in the article 'Defence of Fortresses,'—it is only in small places that a large quantity of casemated cover is essential; therefore the scale of resistance, as demonstrated by Bousmard, will be taken in the calculations for the duration of defence.

The value will then be

$$\frac{fs \sqrt{advr}}{e} \times \text{ the term of resistance,}$$

giving 36 days as the period of resistance to a perfect system.

Now allowing 10 for each unit, the expression will be for this fortress

$$\frac{100 \sqrt{10000}}{10} = 1000.$$

Many attempts have been made to establish some rule for determining the value of fortresses, but with little success; yet some formula is desirable, and the above is given for want of a better, of which the utility will be easier understood in the sequel.

Perhaps if the inventors of system had offered their projects for a special purpose, instead of seeking to give a universal system for all fortresses, their value would have been better appreciated, and the futile attempts to establish an equilibrium between the attack and defence of places never proposed; and, in contemplating the various schemes, it may be questioned whether the art of fortifying places has much improved, as regards the Bastion system, since Vauban's 2nd and 3rd systems.

But the Bastion system is generally deficient in casemated cover; and that which is termed modern or *rasante*, is not wholly free from escalade, the command imperfect, and the final resources against an assault are not complete. The faces of the bastions and ravelins are lengthened without a corresponding security from enfilade, for all angular and polygonal works are necessarily exposed to ricochet fire; and the proposition of fortifying by Cormontaigne, on a straight or convex line, is applicable to any system.

The early Bastion or Italian system (*vide* fig. 2, Plate I.) affords some interesting records of defence, and the deep ditches and great command of the body of the place gave great advantages which were difficult to overcome; and if, instead of the orillons and retired flanks, the latter had been casemated, the construction would have been more perfect: still the Italian system is an interesting study to the Engineer in the Mediterranean, and among the fortresses of Spanish Flanders.

Coehorn, abstracted from trivial details, gave a value to his system so well estimated and explained in the translation from Bousmard; and certain ameliorations proposed by Major Merke render the several traces worthy of notice.

Major Merke (*see* Plate II., Coehorn's System,) proposes—1st. To secure the faces

better from enfilade;—2nd. To give a more judicious and moderate casemated defence;—3rd. Good and secure communications from one work to the other;—4th. The places of arms and covert-way to be better suited to active defence in sorties;—5th. To give good cover to the escarps, and render them difficult to breach;—6th. To increase the flank defences;—7th. To augment the defence of the centre of each front;—8th. By defensive barracks to obtain a double or second line of defence. Major Merke's fronts of fortification vary from 200 to 250 toises; the faces (A E) are 65 toises; the salients of ravelin (G C) extend beyond the front 120 toises; and the prolongation of the faces with the bastions, at 25 toises from the angle of the shoulder: the redoubt of the ravelin, as shewn in the section *g h*, is a casemated tower; but the exterior slopes of the ravelin and lunettes are of earth, with wet ditches; and the glacis planted with willow and other aquatic trees, the stumps of which are to prevent the advance of the sap. This talented Dutch Engineer, who has written on casemated works and their application to redoubts and forts, seems to be equally successful in this project as regards the construction of fortresses in humid soils.

The value of Coehorn's system, according to the formulæ here given, will be

$$\frac{f\sqrt{a d \tfrac{1}{2} v r}}{\tfrac{6}{10} e}, \text{ or } \frac{10 \quad \sqrt{5000}}{5} = 142,$$

limiting the active force for sorties at one-half, on account of the wet ditches, at likewise that of the casemated cover; but Major Merke's project will be strengthened by his ample bomb-proof defensible barracks, and may be estimated thus:

$$\frac{f \tfrac{1}{2} s \quad \sqrt{a d v r}}{\tfrac{8}{10} e}, \text{ or } \frac{50 \quad \sqrt{10000}}{8} = 625,$$

Bousmard's duration of defence for Coehorn's system at twenty-one days, to which seven days may be added for Major Merke's.

Recurring to the *Bastion system;* of which Bousmard says—"qu'on est forcé de reconnoître que cette science a, sans cesse, des contraires à concilier; vous donnez-vous un beau relief* pour rendre difficile l'escalade par la longueur et la pesanteur des échelles qu'il y faudroit employer? vous la facilitez d'un autre côté par la quantité de parties mortes ou vides de feu * * * prenez-vous un commandement considerable sur le terrain et sur votre glacis, pour prolonger d'autant mieux dans les travaux des attaques? vous vous decouvrez trop, et vous livrez, pour ainsi dire, en plein à toute la furie des batteries de l'assiégeant. Voulez-vous au contraire avoir une de ses fortifications rasantes si fort à la mode aujourd'hui, qui ont le mérite de n'être presque pas vues? vous tomberez, en revanche, dans l'inconvénience de ne presque rein voir."

Various projects have been suggested to reconcile these difficulties, as shewn in Plates I. to VIII. of the Bastion system, from the simple trace to the complicated details of Chasseloup, executed at Alexandria in Italy, previous to 1815, thereby quadrupling the expense, and only obtaining double the resistance. But the trace of fig. 6, Plate I., seems to be that adopted in the present day as the perfection of the Bastion system,—to cover the body of the place, and preserve the faces of the bastion from enfilade, by the extension of the salients of the ravelins, giving two dead angles to that work, and rendering the faces still more open to ricochet fire.

If casemated flanks had been given to the redoubts of Vauban's 2nd and 3rd systems, with a counterguard in front, corresponding with Cormontaigne's ravelins,

* "De 35 pieds, qui est celui que l'on prétend sur contre l'escalade."—*Bousmard.*

and a more extensive supply of bomb-proof cover to the inner line, it is conceived that the Bastion system would have been as perfect as possible.

An Inner Line of sufficient height,—whether flanked by tower bastions, or by circular towers, as proposed by Major Merke, or by caponière and réduit, used in the German systems, or even by a loopholed corridor-wall, proposed by Carnot,—is the first essential to a protracted defence; and with this impression, a greater value is here given to Vauban's 2nd and 3rd systems than seems to be admitted in the French schools.

According to our value, Vauban's 1st system is estimated thus:

$$\frac{fs \sqrt{a}}{\frac{4}{10} e} = \frac{100 \sqrt{10}}{4} = 79$$

multiplied by Bousmard's calculated resistance of 19 days.

$$\text{2nd and 3rd systems, } \frac{fs \sqrt{ar}}{\frac{8}{10} e} = \frac{100 \sqrt{100}}{8} = 125.$$

These, with adequate bomb-proof, will give—

$$\frac{fs \sqrt{avr}}{e} = \frac{100 \sqrt{1000}}{10} = 316$$

probable days' resistance, if the ravelins had casemated flanks and counterguards; whereas we value the improvements of Cormontaigne only as

$$\frac{fs \sqrt{ad}}{\frac{6}{10} e} = \frac{100 \sqrt{100}}{6} = 166,$$

from the deficiency of bomb-proofs, and the want of an inner line.

Bousmard's and Chasseloup's traces, not countermined, as

$$\frac{fs \sqrt{advr}}{2e} = \frac{100 \sqrt{10000}}{20} = 500;$$

the vast expense of the construction lessening the value.

It is conceived, likewise, that the modern or *rasante* system, besides being deficient in command, is open to assault by escalade before the close of the siege for want of relief, the escarps not exceeding 25′ 6″, should an enterprising enemy be disposed to make some sacrifice to accelerate the attack.

The French Engineers, however, in their late constructions at Paris and Lyons, appear to have emancipated themselves from the pedantry of their schools, by a judicious application of casemated barracks to serve as an inner line, by the use of the bastionet and *escarpes detachés*, and batteries *à l'Haxo*, (*see* Plates VI. and VII. of the Bastion System.)

Montalembert and *Carnot*, who had just perceptions of the defects of the Bastion trace, invented schemes which have been termed systems. These are based upon theories that have never been satisfactorily worked out, and they are thus become a matter of history in the art of fortifying places. Montalembert conceived, that by securing a preponderance of direct fire, an enemy could never establish his batteries in the first parallel; and Carnot proposed to overwhelm the trenches by a vertical fire, and thus prevent his advance. But the attack of Ciudad Rodrigo, independent of previous well known facts, practically illustrated the contrary; for that place was breached and taken with an inferiority of direct fire, and without the use of mortars at all.

As Montalembert's and Carnot's systems are the foundation of the German and Prussian schools, the value of their schemes should be given.

Thus Montalembert's gives

$$\frac{fs\sqrt{avr}}{3e}=\frac{100\ \sqrt{1000}}{30}=105;$$

and Carnot's, with bomb-proofs, as

$$\frac{fs\ \sqrt{avr}}{e}=\frac{100\sqrt{1000}}{10}=316,$$

both being allowed an ample bomb-proof cover, but open to direct fire.

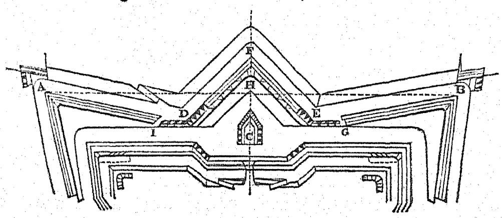
Appendix A. to this article is extracted from the 'Corps Papers,' to demonstrate the defects of the casemated towers of each system; and hence, with all the advantages of well constructed casemates, they are practically the weakest.

In respect to Carnot's vertical fire, without reference to his system, he has estimated the force without considering that the casemates covering the mortar batteries would be destroyed by the besiegers' early batteries before they could have any effect, except when constructed in some collateral work, to take the approaches in flank or in reverse.

The German System.—In analyzing this system, and in discussing its positive and relative value with others, it is necessary to separate those questions adverted to by Major-General Brèze which are foreign to the subject as a system; such as the application of detached forts, which may be placed in front of any trace, whether of the Bastion System, as at Lyons and Paris, or of the German, as at Cologne; as likewise the system of countermines, which may be given to any trace with dry ditches.

The German school, estimated by the construction of one front, as given by Colonel Humfrey, which explains and simplifies the system, as shewn in the diagram,

Fig. 1.—Fort Alexander, Coblentz.*



without countermines, gives the value as

$$\frac{f\frac{3}{2}s\ \sqrt{av}}{\frac{6}{10}e}=\frac{150\ \sqrt{100}}{6}=250.$$

This value, which may be deemed insufficient, arises from a conceived impression, that the German works, called caponières and réduits and casemated flanks, are liable

* *Construction of fig.* 1, *according to Col. Humfrey:*

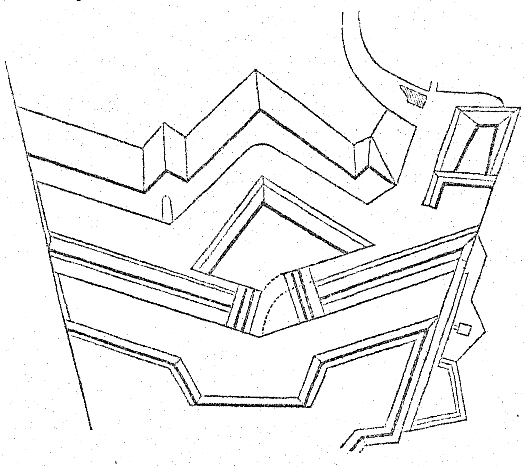
"At the centre of the front A B, construct a perpendicular H I to $\frac{1}{12}$.

"Make the demi-gorges C D and C E $=\frac{1}{7}$, and the capital C F $=\frac{1}{6}$ of A B. The faces D F and E F are equal to $\frac{1}{5}$th of the front A B."

to the same fate as those of Montalembert and Carnot, and therefore the resistance to direct fire is omitted. Appendix A. will again shew, that should the heavier artillery be brought into use in sieges, such as the 68-pounder, of 50 cwt., fired at a low angle, in conjunction with the 8 and 10-inch howitzers, from the second parallel along the ditches, the defensive powers of these works will be greatly lessened before the crowning of the glacis by the besiegers. These observations are not offered for the purpose of entering into controversy with the Prussian school, but as of importance in the application of systems to works of defence in our Service, which has not yet become the advocate of any system.

It is conceived, likewise, that when the counterscarp is in possession of the besiegers, and the descent into the ditch practicable, and the lodgement effected on the ravelins or counterguards, that the injured casemated flanks might be rendered totally useless for defence by a resolute enemy firing small rockets into the embrasures and loopholes; and thus the limited period of twenty-four days is given for the defence of a single front of fortification according to fig. 1.

Fig. 2.—Land front of Citadel at Ehrenbreitstein.



When an inner line is given, as at Ehrenbreitstein, the value, without countermines, in fig. 2, will be equal to

$$\frac{f\frac{3}{2}s \quad \sqrt{a\,v\,r}}{e}=\frac{150 \quad \sqrt{1000}}{10}=474.$$

It may be stated that we have over-estimated the cost of the German system, as well as under-rated the duration of defence, but we are too well acquainted with the great cost of casemated works to be deceived on this point, and Bousmard is our guide for the resistance.

The object of these observations is to give the value of the several systems, and not to object to any trace which may suit the locality and purpose of the work, or to dispute the advantages which the German system gives to strategetical fortresses, and to prevent the adoption of it to all circumstances to which a novel mode of construction is apt to lead the Engineer Officer.

One fact, stated in the description of Montalembert's system, should never be forgotten,—to see is to be seen; and hence, except in particular positions, the pecu-

liarities of the German system, termed caponières and réduits, can be destroyed before the counterscarp is taken by the besiegers by a direct fire.

Finally, the German system is not adapted to fortresses of the third class—such as citadels and places below the heptagon, the system being based upon the advantages it gives for sorties and tactical purposes; and M. Emile Maurice justly observes,—

"Nous croyons qu'elle offre d'ingénieuses combinaisons, et que la guerre de retranchements lui devra beaucoup de ses ressources et de ses progrès."

Table of the Comparative Value of Systems for a Front of Fortification of 400 *yards, according to the above Formulæ.*

Probable expense.*	Description of Fortification.	Assumed value.	Duration of resistance.†
£.			Days.
100,000	Imaginary perfect System...........	1000	36
50,000	Coehorn's System..................	142	21
80,000	„ improved by Merke	625	31
40,000	Vauban's 1st System................	72	19
80,000	„ 2nd and 3rd Systems	125	29
60,000	Cormontaigne's System.............	166	30
200,000	Bousmard and Chasseloup's Systems ..	500	34
300,000	Montalembert's System.............	105	30
100,000	Carnot's System, with bomb-proof	316	18
60,000	German System, single line	250	24
100,000	„ double line.........	474	34

In the selection of systems there are several points ‡ to be considered:

1. The object for which the work is required, whether for strategetical purposes, or as a dépôt, or as a fortress to cover a principal naval or military arsenal.

2. The expense.

3. Whether the place can be relieved; for an enemy may be so strong, or the fortress so isolated, that it may be blockaded and starved out, as at Mantua, Genoa, and Malta.

4. Lastly, the Engineer, without being a partisan of any system, may combine the advantages of several, according to the position and nature of the ground, which may vary from hilly to a low alluvial soil, and adopt one or several systems in one fortress.

G. G. L.

APPENDIX A.§

Report of Experiments carried on at Woolwich in 1822, *against Carnot's Detached Revetment.*

In the summer of 1822, the Duke of Wellington being Master-General of the Ordnance, it was determined to make experiments on the possibility of breaching walls protected by earthen counterguards, as proposed by Carnot, in his System of Defence, by firing over the crests of such counterguards.

It was first desirable to ascertain the smallest elevation at which shot could be

* Taken from the 'Journal des Sciences Militaires,' vol. xxiv. 3rd series.

† Calculated from Bousmard's system of attack.

‡ See Article 'Fortress, Permanent.'

§ From the second volume of 'Corps Papers.'

fired, if it were practicable to throw shot at all, which, clearing the counterguard, should fall sufficiently in their flight between it and the wall to strike the latter low enough to open a practicable breach, and what charge and elevation were most suitable for this purpose; and next it was to be determined whether shot so thrown had sufficient momentum to ruin masonry.

Experiments were accordingly made, with the first object, in twenty-eight days, between August 2nd and September 24th, 1822, by firing over a bank of earth 66 feet long, and in section similar to the upper part of Carnot's counterguard, having its crest 12 feet above the level of the experimenting batteries. The distances from the top at which the different shot would have struck the wall, were known by the height at which they struck a bank of earth thrown up at the proper distance (60 feet) in rear of the counterguard; and for those which struck the ground between the two mounds, by measuring the distance from the foot of that in rear; and all which were stated to strike lower than 12 feet were thus obtained.

The two first days' practice were considered as preliminary: from the results of the others it was decided, that with elevations of 10° and 11°, it was not possible to strike the wall lower than 16 feet from the top; that only $\frac{2}{7}$ths of the shot and shells so fired would take effect upon the wall at all; and of those that did, only about $\frac{1}{28}$th at more than 12 feet from its top, or $\frac{1}{97}$th of the whole number fired. This opinion was formed after 487 rounds from different descriptions of heavy ordnance had been fired, at ranges of 400 and 500 yards, with elevations not exceeding $11\frac{1}{2}$°.

Four hundred and eighty rounds, at similar ranges, were fired at elevations of 15°, and it appeared that between $\frac{2}{7}$ths and $\frac{3}{8}$ths would have taken effect, of which $\frac{3}{7}$ths, or $\frac{1}{6}$th of the whole number of rounds, would have struck the wall lower than 12 feet from its top.

The details are given in the following Table:

Results of Experimental Practice made at Woolwich in August and September, 1822, to ascertain whether it would be practicable to fire shot over Carnot's Counter-guard, and strike the Wall in rear low enough to open a Breach.

Days of practice.	Date.	Nature of Ordnance.	Range.	Charge.	Elevation.	No. of rounds.	Shot or Shells struck the wall from top, at													Total.	Proportion		
							1 to 2 feet	2 to 4	4 to 6	6 to 8	8 to 10	10 to 12	12 to 14	14 to 16	16 to 18	18 to 20	20 to 22	1 to 12	12 to 22		Of rounds which struck the wall.	Of those striking the wall that struck below 12 feet.	Of the whole number of rounds fired that struck below 12 feet.
				lbs. oz.																			
3rd.	Aug. 7.	24-pounder iron, 9 ft.	400 yards.	0 12	10	37	2	5	..	1	..	..	..	..	..	..	..	8	..	8	more 1-5th.		
5th.	9.	Do. do.		1 0	$9\frac{3}{4}$	30	3	2	1	..	4	1	..	..	..	..	..	11	..	11	more 1-3rd.		
9th.	16.	68 carronade wt. shot.		1 0	$9\frac{1}{4}$	30	4	2	1	2	1	2	..	..	..	..	..	12	..	12	2-5ths.		
				1 0	$9\frac{1}{4}$	20	..	2	4	..	2	2	..	..	..	..	..	10	..	10	1-half.		
10th.	19.	Do. do.		1 4	$7\frac{1}{2}$	30	..	2	..	6	..	2	..	..	..	..	..	10	..	10	1-3rd.		
				0 14	$11\frac{1}{2}$	20	1	..	..	..	..	3	..	1	..	..	..	4	1	5	1-4th.		
21st.	Sept. 4.	Do. do.		1 0	$9\frac{1}{4}$	40	..	2	4	2	..	1	..	..	..	..	..	9	..	9	near 1-4th.		
26th.	Aug. 27.	8-inch iron howitzer.		1 6	10	40	3	2	1	1	2	1	..	..	..	..	..	10	..	10	1-4th.		
		Total, not exceeding $11\frac{1}{2}°$ elevation at 400 yards range.	400	..	..	247	13	17	11	12	9	12	..	1	..	..	..	74	1	75	more 3-10ths.	1-75th.	
4th.	Aug. 8.	24-pounder iron, 9 ft.	500 yards.	0 9	$10\frac{3}{4}$	40	2	..	1	2	..	1	1	..	..	..	..	6	1	7	more 1-4th.		
6th.	12.	8-inch. iron howitzer.		1 4	$9\frac{1}{2}$	40	..	2	..	1	1	2	..	..	..	..	..	6	..	6	more 1-7th.		
7th.	13.	Do. do.		1 8	$7\frac{1}{2}$	20	1	..	..	..	1	..	..	..	..	..	..	2	..	2	1-10th.		
		10-inch do.		2 0	$10\frac{1}{4}$	30	2	1	2	1	2	2	1	..	..	..	..	10	1	11	more 1-3rd.		
8th.	14.	Do. do.		1 10	$9\frac{1}{2}$	30	3	1	3	3	2	1	..	..	..	..	..	13	..	13	more 2-5ths.		
11th.	20.	68 carronade wt. shot.		1 4	9	40	2	3	2	4	1	2	2	..	..	..	..	14	2	16	2-5ths.		
15th.	26.	8-inch iron mortar.		1 11	10	40	..	5	2	1	2	1	..	..	..	..	..	11	..	11	more 1-4th.		
		Total, not exceeding $10\frac{3}{4}°$ elevation at 500 yards range.	500	..	..	240	10	12	10	12	9	9	4	..	..	..	..	62	4	66	more 1-4th.	1-16th.	
		Total, not exceeding $11\frac{1}{2}°$ elevation.	..	..	..	487	23	29	21	24	18	21	4	1	..	..	..	136	5	141	more 2-7ths.	1-28th.	1-97th.

12th.	Aug. 21.	8-inch iron mortar.	400 yards.	1 0	15 elevation.	20	..	..	2	..	..	2	1	2	4	..	..	4	7	11	more 1-half.		
13th.	22.	Do. do.		1 0		40	1	2	..	2	..	1	2	1	1	2	..	6	6	12	3-10ths.		
17th.	28.	8-inch iron howitzer.		0 11		50	5	2	4	2	1	7	1	1	1	..	..	21	3	24	near 1-half.		
22nd.	Sept. 16.	Do. do.		0 11		30	1	..	2	3	1	..	2	1	2	..	1	7	6	13	more 2-5ths.		
23rd.	17.	16-inch do.		1 3		30	..	..	1	1	1	2	1	3	2	..	2	5	8	13	more 2-5ths.		
24th.	18.	Do. do.		1 2		30	..	..	1	4	1	..	1	1	2	..	3	6	7	13	more 2-5ths.		
20th.	3.	68-pr. carron. wt. shot.		0 11		40	3	1	3	4	..	2	1	..	2	..	..	13	3	16	2-5ths.		
25th.	19.	Do. do.		0 13		30	..	1	3	1	3	1	..	1	..	3	..	9	4	13	more 2-5ths.		
		Total, at 15° elevation and 400 yards range.	400	..	15	270	10	6	16	17	7	15	9	10	14	5	6	71	44	115	near 3-7ths.	near 2-5ths.	
14th.	Aug. 23.	8-inch iron mortar.	500 yards.	1 5	15 elevation.	40	1	1	1	1	..	..	3	3	..	1	1	4	8	12	3-10ths.		
18th.	29.	8-inch iron howitzer.		0 14		40	..	..	2	1	4	1	3	1	..	..	..	8	4	12	3-10ths.		
28th.	Sept. 24.	Do. do.		0 14		30	1	..	..	..	1	..	..	..	2	..	1	2	3	5	1-6th.		
27th.	23.	10-inch do.		1 8		30	2	..	..	..	2	3	2	1	2	1	1	7	7	14	near 1-half.		
19th.	2.	68-pr. carronade shot.		0 13		40	1	1	..	2	..	2	3	2	2	1	..	6	8	14	more 1-3rd.		
26th.	20.	Do. do.		1 0		30	1	1	1	1	1	1	..	..	..	..	1	6	1	7	near 1-4th.		
		Total, at 15° elevation and 500 yards range.	500	..	15	210	6	3	4	5	8	7	11	7	6	3	4	33	31	64	more 3-10ths.	near 1-half.	
		Total at 15° elevation.	..	..	..	480	16	9	20	22	15	22	20	17	20	8	10	104	75	179	near 3-8ths.	near 3-7ths.	5-32nds.
		Total.	..	..	..	967	39	38	41	46	33	43	24	18	20	8	10	240	80	320	about 1-3rd.		

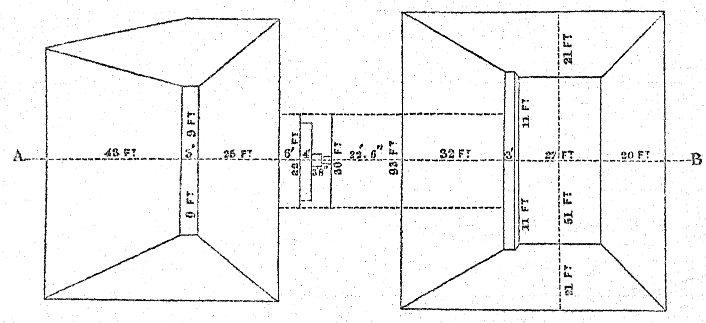
The first two days being considered preliminary, their practice is not included in the preceding Table.

Of the 967 rounds, only 144 fell short; and of the 503 rounds remaining unaccounted for, it was considered that all except 37 would have struck the bastion in rear of the wall, if, according to the arrangement of Carnot's system, such work had been constructed there.

The experiments having proved that shot or shells could be fired at angles of 15°, so as to strike the wall, even at its foot, it remained to be determined whether, when so fired, their momentum was sufficient to breach it, the small charges necessarily used to attain the first object rendering this doubtful.

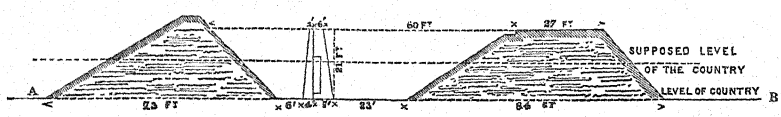
A portion, 30 feet in length at bottom and 28 feet at top, of a wall corresponding to that proposed by Carnot, was accordingly built with bricks, in the summer of 1823.

Fig. 1.—Plan of the Rampart, Wall, and Counterguard.



It was 21 feet high, 6 feet thick at top, 7 feet at bottom, and one loophole in a recess; to support which, in continuation, it was strengthened by a buttress, 4 feet square, at each end, the whole carefully built and well cemented.

Fig. 2.—Section on the line A B.



An earthen counterguard was thrown up in front, and a mound in rear, the former being at the distance, and having the same section, as that proposed by Carnot: the latter represented his bastion, being at the same distance, but was only carried up 4 feet higher than the wall, and was therefore 8 feet lower than that proposed by him.

On the 5th of August, 1824, a year after the completion of the wall, eight 68-pounder carronades, in battery 500 yards from the crest of the counterguard, three 8-inch and three 10-inch iron howitzers, at a distance of 400 yards,—in all fourteen pieces,—fired 100 rounds each in about six hours, the howitzers firing live shells filled with powder, and the carronades solid shot.

A practicable breach, 14 feet in width, was made by their fire, and the buttresses were much injured (see figs. 3 and 4).

Fig. 3.—Front View of the Wall, shewing the effect of the first and second day's fire.

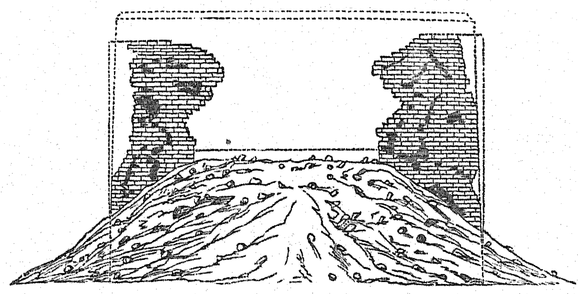
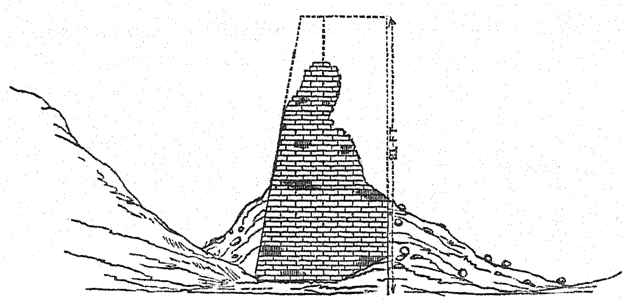


Fig. 4.—Side View of the Wall after the second day's fire.



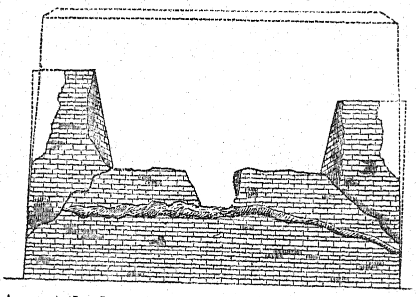
The splinters of the shells proving inconvenient to the men in the nearer battery, the loading of the shells was diminished.

On the 6th of August the firing recommenced from eight 68-pounder carronades, at 500 yards; two 8-inch iron howitzers, and four 10-inch ditto, at 400 yards: 50 rounds per piece were fired in two hours, when the breach was examined, and found to be complete in every respect, and the buttresses to be in the ruinous state shewn by the darker shades of figs. 3 and 4.

On the 5th and 6th of August, two of the 8-inch and two of the 10-inch howitzers, and four of the carronades, had been placed on high traversing platforms, so as to raise them nearly to the natural level of the country, according to Carnot's system; but His Grace the Master-General, who examined the breach at this period, having given directions that all the ordnance should be placed on common or ground platforms, the use of the traversing platforms was discontinued. It had previously been observed that no advantage or superior accuracy of fire attended raising the guns.

His Grace also ordered that the rubbish should be cleared from the breach; and it was found that the wall was about 5 feet in perpendicular height in front, with a rounding of rubbish of about $2\frac{1}{2}$ or 3 feet at top, and about $8\frac{1}{2}$ or 9 feet in height towards the rear (fig. 5).

Fig. 5.—Front View of the Wall when the Rubbish was cleared away from the BREACH, after the second day's fire.



On the 11th of August the batteries recommenced their fire from eight 68-pounder carronades, at 500 yards, and six 10-inch howitzers, at 400 yards; when 85 rounds from each howitzer, and 100 rounds from each carronade, were fired in three hours and a half, by which time the wall and buttresses were one mass of ruin (see figs. 6 and 7).

Fig. 6.—Front View of the Wall after the third and last day's fire.

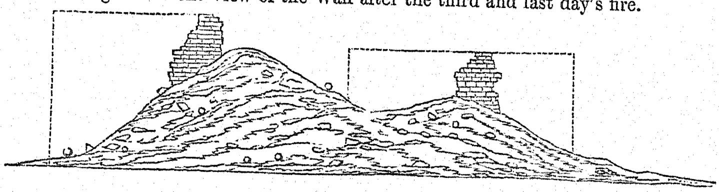
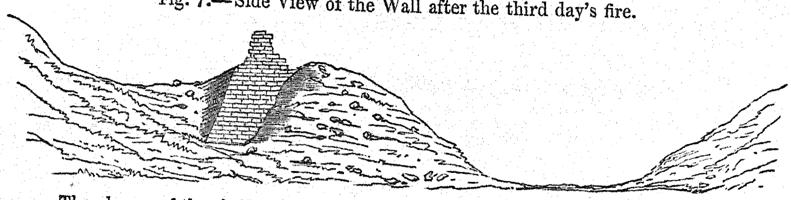


Fig. 7.—Side View of the Wall after the third day's fire.

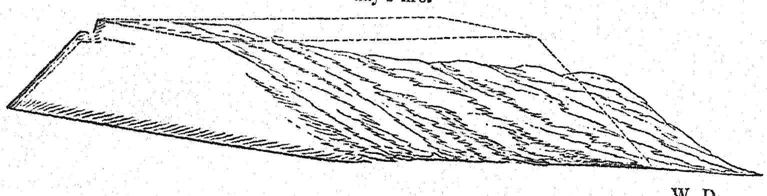


The charge of the shells had been so much reduced, to avoid splinters reaching the batteries, that a considerable number did not burst.

From careful observation, it appeared that about one-fourth of the shells, and one-fifth of the shot, struck the wall.

The increased rapidity of fire is remarkable, that of the third day being nearly double that of the first, although the reduction in the height of the wall, from 21 to 5 feet, rendered the operation obviously more difficult. A sketch of the counterguard (fig. 8) shews the effect of the shells on its superior slope.

Fig. 8.—General View of the Counterguard in front of the Wall after the last day's fire.



W. D.

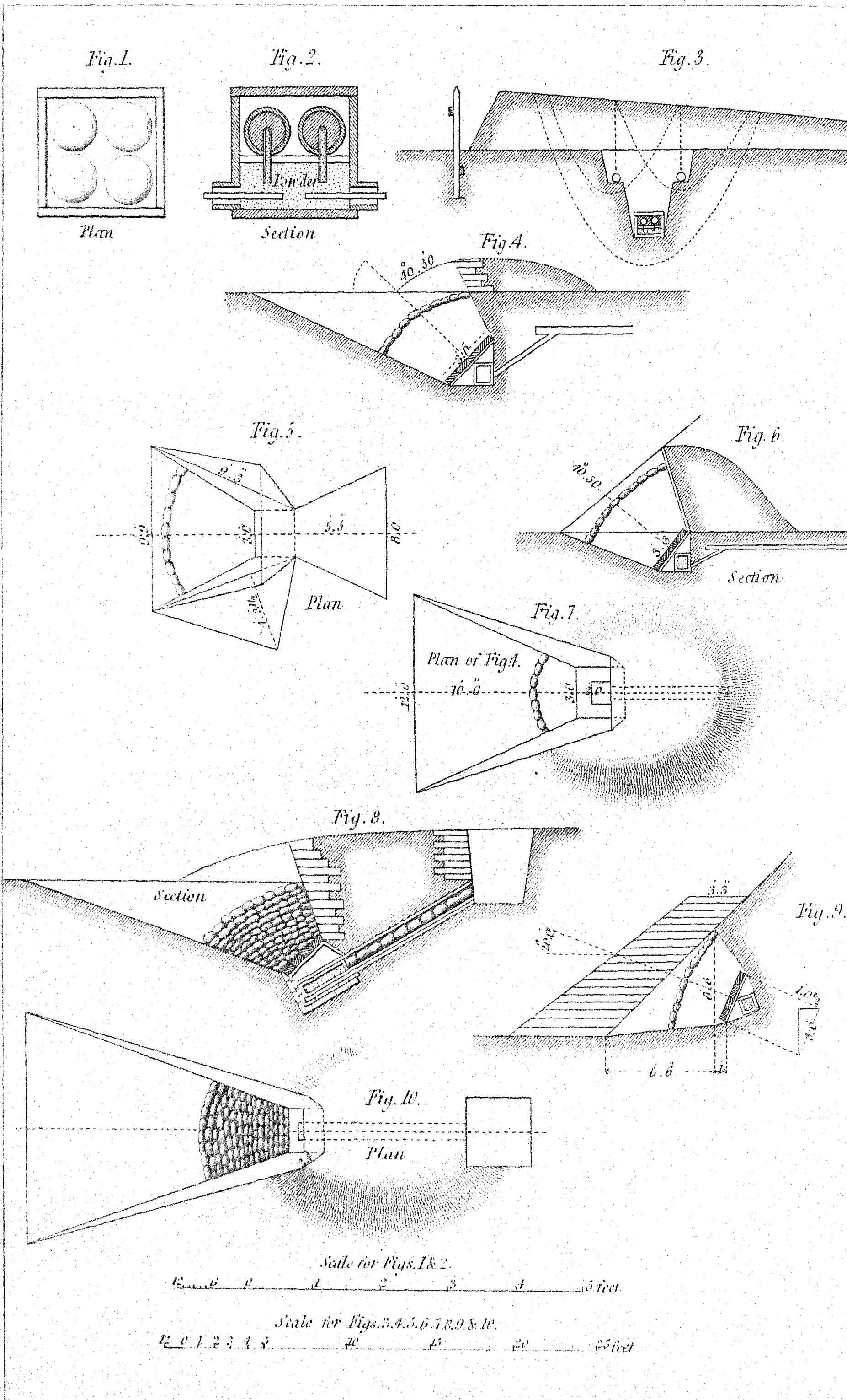


Fig. 1.
Plan
Fig. 2.
Powder
Section
Fig. 3.
Fig. 4.
10.30
3.0
Fig. 5.
9.3
3.0
5.3
8.0
Plan
Fig. 6.
10.30
3.8
Section
Fig. 7.
Plan of Fig 4.
12.0
10.0
3.0
3.0
Fig. 8.
Section
Fig. 9.
3.3
6.6
6.6
Fig. 10.
Plan
Scale for Figs. 1 & 2.
1 2 3 4 5 feet
Scale for Figs. 3.4.5.6.7.8.9 & 10.
12 0 1 2 3 4 5 10 15 20 25 feet

FOUGASS.*

COMMON FOUGASSES.

Fougasses Ordinaires.—These are small mines made by simply placing a box of powder at the bottom of a pit excavated for the purpose, from 3 to 4 yards deep. They are usually fired by means of an auget led up the side of the pit, and then parallel to the surface of the ground, at a depth of from 2 to 3 feet.

The bottom of the pit should be made firm; the box containing the powder and the auget well pitched over, to keep out the damp; and in filling up the pit again, care should be taken that the earth is well rammed, and the ground around turned up for some distance, so that nothing may indicate the position of the fougass.

SHELL FOUGASSES.

Fougasses à Bombes.—These are formed by burying shells which are connected together so as to explode simultaneously, either in the place where they have been lodged, or as they come to the surface of the ground. The shells are placed in the upper part of a box, which is divided horizontally by a partition with holes in it, to allow the fuzes of the shells to project down through them.

In the lower part of the box sufficient powder may be placed to project the shells to the surface of the ground; or in case it is intended that they should explode where they are lodged, the powder hose may be connected directly with them. These are principally used for the defence of the glacis, and are represented in figs. 1, 2, and 3, in the Plate.

Single shells may also be used: in this case the

8-inch	should be	placed	3	feet deep,
10-inch	,,	,,	5	,,
13-inch	,,	,,	6	,,

STONE FOUGASSES.

Fougasses Pierriers.— An excavation, in the form of a frustrum of a cone or pyramid, corresponding nearly with the form of the entonnoir of the intended fougass, is made; and a box of powder, to project the stones or other projectiles with which the excavation is to be filled, is placed under a 2 or 3-inch board at the bottom of it. The axis of the excavation should be inclined to the horizon at an angle of about 40°, and the sides inclined to the axis at an angle of 24°. Care should be taken that there is sufficient weight over the fougass to make the line of least resistance correspond with the axis.

As the effect of these mines is nearly the same whether the conical form is adopted or that of the frustrum of a pyramid, and as this latter offers great advantage from the simplicity of its form and the greater rapidity of execution, it has not been thought necessary to give directions for the construction of the ellipses of the former.

Figs. 4 and 5 represent the plan and section of a fougass, which, with a charge of 60 lbs. of powder, will throw from 3 to 4 cubic yards of bricks or stones from 40 to 50 yards, spreading over a nearly equal breadth.

In no case should more ground be broken than is absolutely necessary. If it is firm, an excavation may be made at once, of the form indicated in fig. 5; but if the ground is bad, the back should be revetted with sods, as in fig. 8. The auget is placed in a trench of about 1 foot wide by 2 feet deep.

Figs. 6 and 7 represent the plan and section of a fougass, in which the back, sides, and bottom are made of plank, of the dimensions given. In bad ground this is a good

* By Captain James, R. E.

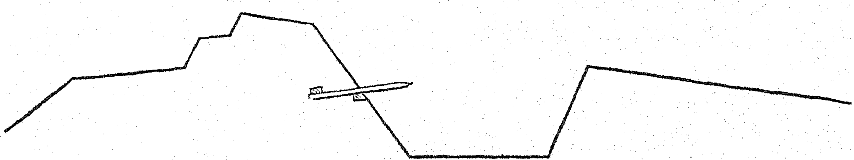
plan; indeed it is advisable to use wood for the support of the back wherever there is under-cutting.

This plan was tried experimentally at Athlone, in 1843. It is very readily executed, and produces a very good effect.

Figs. 8 and 10 represent the method which is used when it is not wished to charge the fougass ~~but only~~ till just before it is intended to fire it. In other cases the powder-box is slipped down a sort of shoot, which is immediately filled with sand-bags; and the pit in rear of it, as well as the trench for the auget, filled in with earth.

Fig. 19 represents a method by which a more *rasante* fire may be obtained, and which might be employed for the purpose of flanking ditches. In this case the axis is inclined about 20° to the horizon; the sides are inclined to each other at an angle of 45°. A revetment of sods is represented, for the purpose of confining the charge to the direction of the axis.

FRAISE.—*Fraises* are palisades laid horizontally, or nearly so, and they are fixed together in the same way: they have been usually placed on the berm of works, and may be considered the smallest obstacle for defensive purposes; they are, besides, expensive, and difficult of execution, and are therefore rarely applicable to field-works, and can only be fixed in permanent fortification advantageously, as explained in the diagram.



It has been found by experience,* that the fraise, in escalading works, serves as a footing rather than an obstacle, when placed on the berm.

When works are not revetted, and the exterior slope, as above, is at an angle of about 45°, and accessible, the fraise may be applied if flanked by a caponière. (See also the Article 'Caponière.') G. G. L.

FURNACE, SHOT.†—The furnace now submitted is of wrought iron: the exterior dimensions are, 37 inches long, 23 inches broad, and 24 inches deep; outside case ¼ inch; inside frame ⅛ inch; bound with ¼-inch straps of iron; can be taken to pieces at pleasure by removing six screw-bolts; will contain fifteen 32-pounder shot, placed on three wrought iron bars, 2¼ inches in diameter, not fixed. The chimney is 2 feet 6 inches high; the flue 14 inches by 6 inches, made in two pieces. The whole mounted on four cast iron trench-wheels, 18 inches in diameter. Rings are fixed to the bottom of the frame, to which drag-ropes may be attached, for the purpose of transporting the machine; the weight complete (but without shot and fuel) being about 720 lbs.

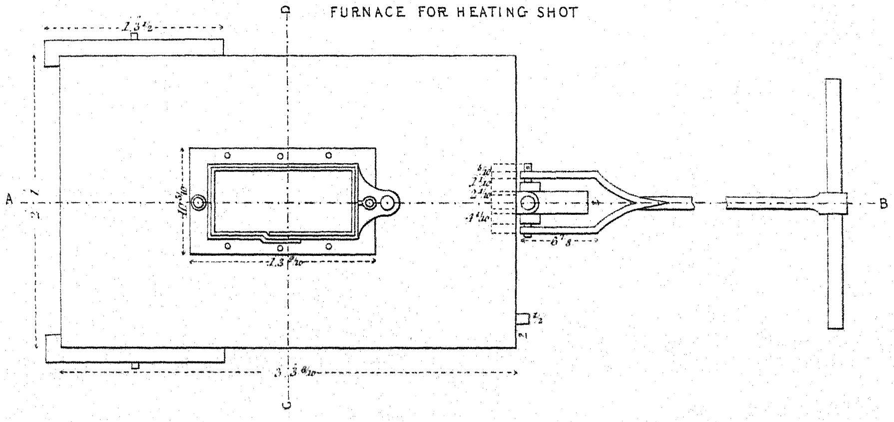
Captain Addison estimates the expense of the machine complete at £8,—

"After repeated trials before a Committee, ~~who~~ they reported the following as a fair estimate of the powers of this new portable shot furnace. Being charged with a quantity of shavings and light wood, ½ bushel of coals, and 2½ bushels of coke, the

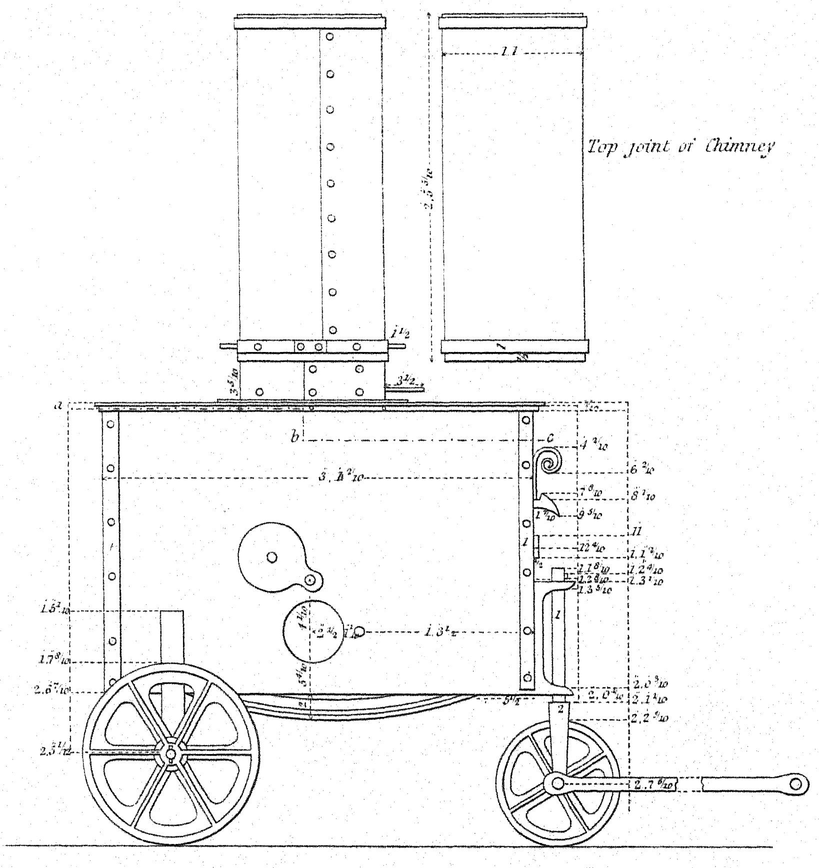
* See Jones's 'Sieges,' vol. i. page 175, third edition, and fig. 12 to Article 'Escalade.'

† By Captain Addison.

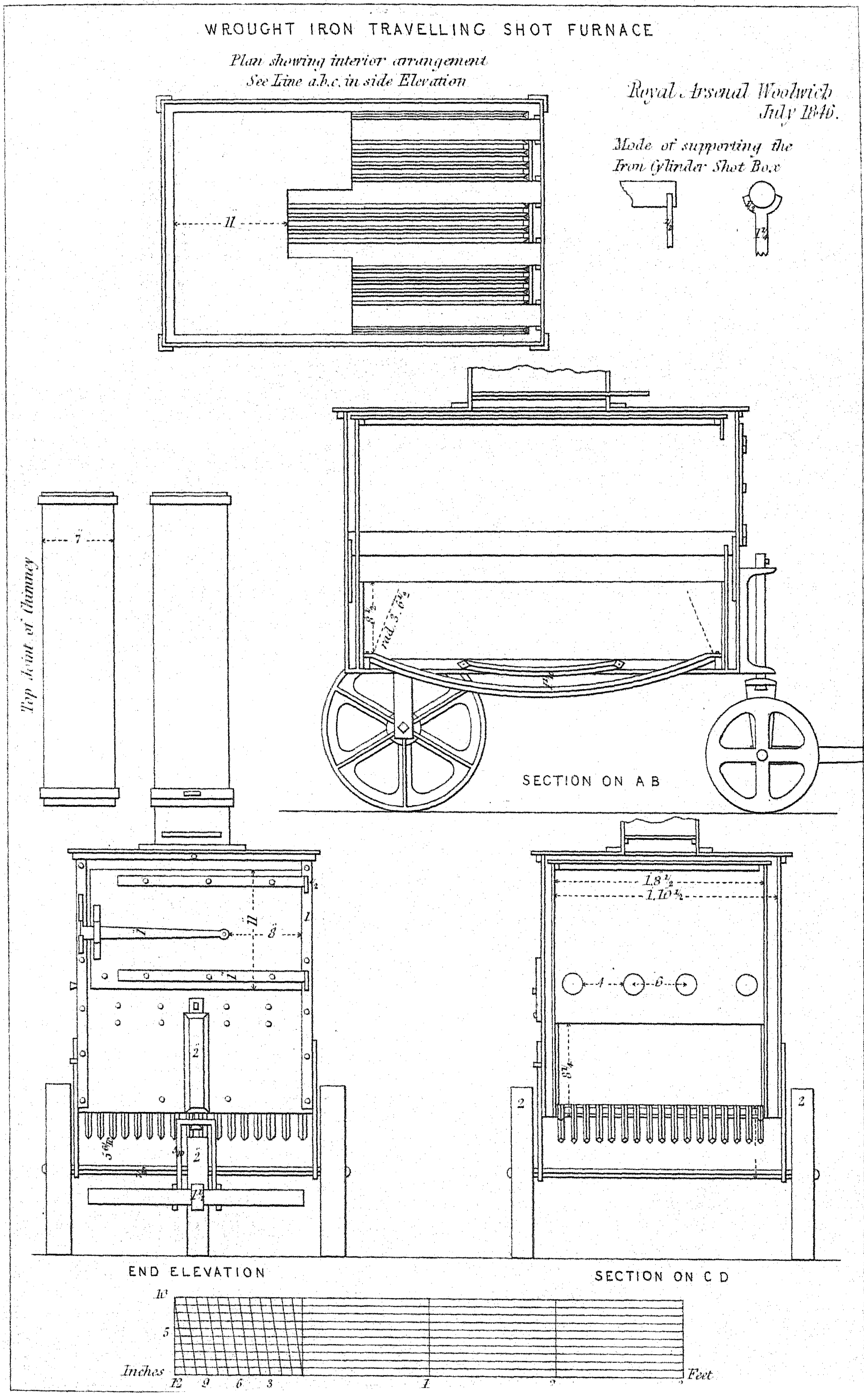
PLANS SECTIONS AND ELEVATIONS OF CAPTN ADDISONS
FURNACE FOR HEATING SHOT



PLAN



SIDE ELEVATION


WROUGHT IRON TRAVELLING SHOT FURNACE
Plan showing interior arrangement
See Line a.b.c. in side Elevation
Royal Arsenal Woolwich
July 1846.
Mode of supporting the
Iron Cylinder Shot Box
Top Joint of Chimney
SECTION ON A B
END ELEVATION
SECTION ON C D
Inches
Feet

fire was lighted and allowed to burn twenty minutes: fifteen 32-pounder shot were then put in; in forty minutes they were serviceably hot, and in one hour and a quarter from the first lighting of the fire they were red-hot: these shot were removed, and fifteen fresh 32-pounders placed on the bars in the furnace: in twenty minutes these shot were red-hot; there was no fuel added. These last shot remained red-hot for four hours. It is therefore to be assumed, that in an hour and a quarter, with this furnace, you can have fifteen 32-pounder shot red-hot, and a succession of this number (fifteen) every twenty minutes afterwards, and by mending and adding to the fire, probably every quarter of an hour afterwards; and that they may be kept red-hot for a very long time, and remain so at inconsiderable trouble and expense.

"The fuel for charging the furnace for the trial described may be estimated at two shillings. It was found an improvement to add 6 inches to the height of the chimney, and to make it 3 feet in the last trial. The bottom of the furnace (or grate) was altered to seventeen $\frac{1}{2}$-inch wrought iron bars, placed diagonally.

"The Committee was of opinion that the new portable shot furnace, then submitted by Captain Addison, was an improvement upon that formerly submitted and reported on by the Committee, 13th December, 1845, in as much as it is more portable and convenient, and less expensive: and as none of the former pattern have been made, the Committee recommended that any shot furnaces required should be of the new pattern." (See Plates I. and II.)

See P. 185 & Pyrotechny.

FUZE FOR MINES.—That in most general use is powder hose, which is made of strips of strong linen or calico, sewn together, and filled with powder; these when full vary from $\frac{1}{2}$ an inch to an inch in diameter. The hose is attached to the charge, and laid in casing tubes to secure it from damage in tamping: these tubes are made from two pieces of wood, with a groove about $1\frac{1}{2}$ inch wide and $\frac{3}{4}$ inch deep cut in each, one being placed upon the other, and fastened to it with wooden pegs as soon as the hose has been inserted between them.

To the end of the hose furthest from the charge, a piece of portfire, about 4 inches in length, is attached, and moist clay is kneaded round this, leaving the end alone free, thus preventing the possibility of the hose igniting until the portfire be burnt out, which affords ample time for the Officer who fires to escape.

A very good substitute for powder hose is Bickford's fuze, which is a tube of powder sewn round with tarred twine, and the outside covered over with pitch. This requires no casing, as from its construction it is not liable to be damaged by the tamping, and it is fired without any portfire being attached to it. It burns at the rate of 12 feet in five minutes, and when once lit cannot be extinguished even by water. It is procured from the maker in coils, having the appearance of thin rope.

E. C. de M.

G.

GABIONS.*—The dimensions of the gabions to be shewn in the regulations of the dépôt; the smallest admissible size being the sap gabion, 20 inches exterior diameter, and 2 feet 9 inches high, weighing from 25 to 30 lbs., as taught at Chatham. There will be also Battery Gabions, and Stuffed Gabions or Sap Rollers.

* From Notes of Major-General Sir J. Burgoyne.

A proportion of the party will select the stakes from the materials brought into the dépôt; they must be as straight as can be obtained, and something longer than the intended final dimension. A few men (carpenters, if they can be spared) will be employed as a squad in pointing one end; after which, another small party will saw off the other end to the exact length. The next squad will strike circles of the given diameter on the ground, and fix the stakes ready for wattling, keeping them to the required height by a gauge-stick: by this means the heads and points of the stakes will be level, and the whole will stand firm. The remaining men, in squads of three, wattle and finish the gabion: great expedition is gained by this division of labour. The party to supply ten squads, actually wattling gabions, will be about thus:

Selecting stuff	3 to 6
Pointing pickets	3
Trimming do. to lengths	3
Fixing do. in circles	3
Wattling, in 10 squads	30

From 42 to 45 men, or half as many again as those employed in wattling.

The non-commissioned Officers will be distributed amongst the parties, especially with those who are sent to select the stuff.

Fir-wood gives the best stakes, being light and straight; large stakes may be split, as it is not essential that they should be round: dry wood, when it can be procured, is better than green for this part of the work. Willow, and all kinds of pliant green wood of sufficient thickness, is proper for wattling. The green dwarf oak will answer, but not well. The rods should be strong, both ends brought inside, and the web well hammered down with a hand mallet as the work goes on. When the rods are too thick, they may be split in two, but the bark must be kept outside. If the leaves are left on, it will make the gabion loose and feeble, but this requires vigilance, as stripping takes time and gives trouble. The small twigs which can be laid smoothly may be allowed to remain, as they give strength.

When finished, the gabion is to be raised out of the ground bodily by a stick thrust under the wattling. The upper and lower few rows must be bound up at unequal depths with slender twigs, or spun yarn, at three or four points on the circumference.

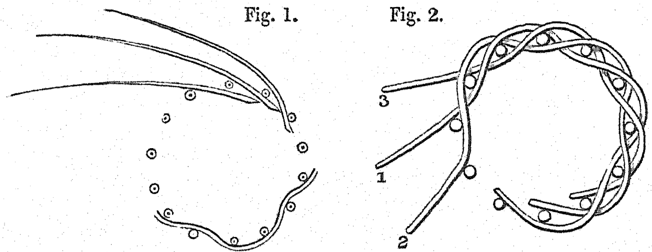
The party may be tasked at from 1 to 4 sap gabions per man per day, and paid for extra work besides. They will require hand-saws and bill-hooks.

When the web of a gabion is made by a single rod being worked round, it is called *randing:* this requires an odd number of stakes. When a flat band of three or four rods is worked in the same manner, it is called *slueing:* this is common in basket-work. When two rods are used, crossing each other, it is called *pairing:* working with more rods than two, is denominated *waling*, and will now be detailed, as being the best.

Figs. 1, 2, shew this process as effected by three only; but four, or even five, may be used conveniently. All that is to be observed is that each rod is successively twisted over and outside those before it, passing as many pickets or stakes (before being brought inside) as there are rods to be waled. As soon as a rod has passed behind one stake, it should be brought out again, or the work will be more polygonal than circular, especially in small gabions.*

* The preceding paragraph has been abridged from the Instructions by Major-General Pasley on this subject.

Fig. 1. Fig. 2.



The Portuguese soldiers would each make four gabions, 2 ft. diameter by 2 ft. 6 in. high, per day; stuff very good, and delivered. They were paid 4*d.* for each such gabion.

OF SAP ROLLERS.*

"Finding by experiment that a large gabion, 4 feet in diameter, if stuffed with small brush-wood, was not musket-proof, but if filled with pickets, perfectly unmanageable, the sap roller was adopted by us at Chatham in preference."†

The sap roller is a hollow cylinder, formed by making two concentric gabions, each 6 feet long, one of 4 feet in diameter, but the other not exceeding 2 feet 8 inches, so as to leave an interval of 8 inches all round between these two, which is stuffed with pickets of hard wood, not less than one inch thick at the tip. If willow be used, the diameter of the smaller gabion must be diminished some inches, in order that more pickets may be introduced.

The pickets and rods of which these gabions are made, must be much thicker than those of the sap gabions before described, as the object is strength, not lightness. The rods of the web to be paired in forming the body of each gabion.

Sap rollers ‡ serve as substitutes for mantlets. In the single sap, one sap roller is used; in the double sap, two of the ordinary size are used with one of a smaller size covering the interval in rear: it may be only 3 or 4 feet long, and rather less than 4 feet in diameter.

GALVANISM.§—Although it cannot yet be said that any positive knowledge has been acquired of the nature of electricity,—whether it is to be considered as one of the primary forces with which all matter is imbued, or as a property called into action by these forces, or as a single or as two invisible highly attenuated fluids,—the continued researches into the effects accompanying, if not proceeding from its development, have been the fruitful source of most important practical discoveries. In this uncertainty as to its nature, electricity shares with heat and light, as each is still spoken of, and often reasoned upon, as a fluid, though neither possesses those properties, specially that of weight, inherent in the bodies properly called solid, liquid, or gaseous. In the attractions and repulsions which it produces there is also an analogy with the effects of light and heat, as their intensity is, like that of gravity, in an inverse proportion to the square of the distance; and it is from these and other analogies that philosophers have been led to surmise that gravity, electricity, magnetism, heat, light, chemical affinity, and even in the animal kingdom nervous susceptibility, may merely be different forms of action of one great force; or, as M. Paul Erman asks, "Are the forces that govern the interior constitution of bodies two in number, and essentially distinct; or do the effects usually called chemical,

* At the suggestion of Capt. J. M. F. Smith, R.E. † From Major-Gen. Pasley's Instructions.

‡ Sap rollers at Chatham are now made with a bilge like a cask, giving great facility in moving the sap roller forward.—*Editors.* § By Major Portlock, R. E., F. R. S., and F. G. S.

proceed from the same cause as those to which we give the appellation of mechanical? The future progress of science depends on the solution of this problem, which the recent development of physics has brought almost entirely within the province of electricity."

Admitting then the obscurity which still hangs over the true nature of electricity, and considering the term electric fluid or fluids as only a provisional and useful mode of expression, philosophers have observed in the modes of its development two different types, which they have designated by the names,—

1. Statical electricity.
2. Dynamical electricity.

To the first of these belongs the electricity produced by friction in the electric machine, which, to produce any great effect, must be accumulated, as it is in the clouds, or in isolators, and which is then, by combination with the electricity of an oppositely electrified body, immediately discharged, and neutralized. A combination of Leyden jars forms in this manner what is called an Electrical Battery.

To the second belongs the electricity of the Voltaic Battery, which is carried along the connecting wires, and forms a continuous stream, so long as the chemical actions producing it are kept up. This therefore is the electricity more immediately under consideration in this article, having been called Galvanism from Galvani, who, in 1790, first noticed the muscular contractions of animals produced by the contact of metals, which remarkable fact, in the hands of Volta, became the foundation of the voltaic pile.

As the discovery of this most important branch of electricity was derived from the excitement of electrical action in the animal kingdom, so it is remarkable that distinct apparatus for the exhibition of electrical forces have been ascertained to form part of the organization of certain animals of the class fishes. These are the gymnotus electricus or electric eel, the silurus electricus, the trichiurus electricus, the tetraodon electricus, the raia torpedo which now forms the type of the genus torpedo of which there are several species, and generally all the species of the genus raia. Of these the most remarkable are the gymnotus electricus and the torpedo. In the gymnotus there are two pairs of electric organs, of different sizes, taking up about one-third of the whole fish: they are formed of longitudinal thin membranous septa, crossed by similar transverse septa: the distance between the longitudinal septa, of the large pair of organs, some of which extend nearly the whole length of the body, is, in large fish, nearly half an inch; and between the transverse septa, $\frac{1}{240}$th part of an inch; so that the whole organ is divided into a vast number of cells. The distance between the longitudinal laminæ of the smaller pair of electric organs is only $\frac{1}{20}$th of an inch. These fishes vary in length from 3 to 4 feet, though some are said to be much larger; and so great is the power of the shock, that horses are stunned by it; and it is in this manner that they are captured in South America, wild horses being driven into a lake where they are known to abound, and when they have exhausted themselves by frequent shocks, they become an easy prey to the Indians. It is to be observed in this case that the animal has not a power to keep up a continued succession of shocks; but though it may in the first instance augment the intensity of the shocks, it soon exhausts its power, and requires a period of rest for its recovery.

In the torpedo there is an electric organ on each side, being situated between the cranium and gills, and the cartilage of the great pectoral fins; they are about 5 inches long, 3 inches broad in front, and about half an inch broad behind, extending from the anterior extremity of the animal to the transverse cartilage which divides the thorax (or chest) from the abdomen (belly). Above and below, the electric organ is covered by a fibrous membrane, and at the sides it is closely connected with the skin, having a second fibrous layer, the fibres of which are transverse to those of the first, under it. The organ within these membranous coats is formed of perpendicular columns, reaching

from the upper to the under surface of the body. The diameter of the columns is about $\frac{9}{10}$ths of an inch, and their figure irregular, varying generally from the hexagon to the pentagon; the coats being very thin and transparent, and the columns closely connected together by a kind of loose net-work of tendinous fibres passing transversely and obliquely between the columns. The columns are divided by horizontal partitions, placed at very small distances, and forming numerous interstices. The number of columns in each organ of a torpedo 18 inches long, was 470; and in one $4\frac{1}{2}$ feet long, 1182, and the number of transverse partitions in one inch, 150. The numerous cells of both the gymnotus and the torpedo are filled with a gelatinous fluid, and the nerves connected with them are both numerous and massive. This latter consideration of the great amount of nerves bestowed upon these organs, and the fact that the animal can give or withhold the shock at his will, afford strong support to the opinion that the apparatus is charged by an instantaneous nervous excitement, and the temporary loss of the power by exhaustion corresponds to the ordinary debility consequent upon any too long continued exercise of nervous power.

The researches of M. Robin have shewn that in the ordinary rays, so closely allied to the torpedos, the electric organs do exist, but not in the position assumed by preceding anatomists; they are placed on each side of the tail, are about the thickness of the index finger, and 13 inches long. Each organ is a flattened cylinder, formed of longitudinal piles of polygonal discs, arranged in layers from two to four in number. The discs are separated by a gelatinous tissue similar to that of the columns of the torpedo and of the cells of the gymnotus. In each then of these animals there is a peculiar arrangement of the electric apparatus, but in all there is a power inherent in the animal of charging it; and although resembling in some respects the voltaic apparatus, it is rather to be referred to the electric battery for analogy.

In addition to the extreme interest attached to the subject itself, these remarkable electric organs, bestowed by nature on animals, deserve special study, as exhibiting powerful apparatus in a comparatively small space and of very simple form. In rendering such study practically useful, the imitation ought not to be sought in any mineral combination, (as was done in the construction of the artificial torpedo by Cavendish,) but in the use of organic substances properly combined. In any case these natural electric apparatus are full of interest and instruction.

In admitting the different mode of development of electricity in the statical and dynamical arrangements, it must not be supposed that there is any difference in the electricity itself: the electricity is the same. In the development by friction, as in the first, heat seems to be an important agent, and a new name has therefore been framed to express this peculiar relation of the electricity, viz. *tribothermic electricity.* M. Paul Erman has suggested that such electricity may be substituted for the galvanic in one of its most interesting practical applications, namely, in acting on and deflecting the magnetic needle in the electro-magnetic telegraph. He observes that "the electric telegraph is becoming popular at present, but it generally requires an apparatus which is variable in its effects and expensive in its employment. It would therefore be advantageous to substitute the purely mechanical principle of the tribothermic telegraph. By removing the stopper of a wheel-work, a disc of bismuth is made to rub against another of antimony, and at the same instant the needle at the opposite extreme of the rheophore is put in motion. I have ascertained the instantaneousness of this operation for tolerably considerable distances, and employed as a signal it would have the advantage, that after the interval of days or months, the clock-work being put in motion, the effect of friction would necessarily take place; whereas in the voltaic telegraph there would be a chance of the combination having lost its efficacy by the lapse of time. Such a suggestion, from a philosopher like

M. Erman, deserves consideration in forming combinations for this interesting application. The present systems of the electro-magnetic telegraph will be described in connection with preceding systems of telegraph under the head 'Telegraph.'

The power of deflecting the needle, and of changing its poles by passing through it an electric current, the pole being changed from north to south, or from south to north, according as the current is made to pass from the positive to the negative, or from the negative to the positive poles, has been applied also to locomotion.

In the arrangement adopted by the Rev. Mr. McGauley, a catholic clergyman of Dublin, the ends of a strong iron bar were placed between the poles of two powerful horse-shoe magnets, the bar being connected with the machinery for producing motion. On the wires of two small voltaic batteries being connected with the magnets, the poles were reversed, and the north pole repelled the one end and attracted the other of the bar. On removing the wires, and making the contact in such a manner that the electric current should pass in the opposite direction, the poles were again reversed, and of course repelled and attracted the opposite ends of the bar; and thus an oscillating movement was produced by the alternating course of the current. Mr. McGauley succeeded in putting in motion a small model carriage, but the short space through which the magnets operated, limiting the stroke or movement, he does not appear to have proceeded further with his researches. A boat, however, was kept in motion by an apparatus of this kind, independently invented by the Russian philosopher, Professor Jacobi; but a more perfect application of the principle is yet a desideratum.

On the other most important practical applications of galvanism, mentioned under the head 'Electricity,' it is only necessary here to add a few remarks.

1. *Electrotyping.*—The decomposition of metallic salts by the electric current has been fully described, and the use of this property in coating with the reduced metal the surface of some other metal forming a negative element of the combination has been most clearly explained by Captain Larcom; but two recent scientific applications of this process deserve to be noticed, namely, coating the steel springs of watches with gold by the eminent chronometer-maker, Mr. G. P. Dent, and the coating of magnetic needles, also with gold, by Professor Christie. This process did not generally interfere with the magnetic properties of the needle, and if they were even found to have been diminished by the act of electrotyping, a new application of the magnet in the usual way restored them. I need not point out that this experiment shews that a thin coating of gold on a copper lightning conductor will not interfere with its conducting property, although it will preserve it from any unfavorable chemical action.

2. *Explosion of Gunpowder.*—Under 'Electricity' the system adopted, and the form of Battery hitherto used, have been explained fully by Capt. Hutchinson. As however it will be desirable to simplify that arrangement for military purposes, it is necessary to state the difference which has been observed in the conditions required for producing the two effects of heating and of chemical decomposition.

In effecting chemical decomposition, or generally in producing chemical effects, it has been found that the power increases with the number of the plates, or rather in proportion to the surfaces; but in producing heat or ignition, it is observed that the increase is as the squares of the surfaces of the individual plates: hence, in a voltaic battery composed of 20 plates, 1 foot square, the heating effect will be only one-quarter that of a battery composed of 20 plates, 2 feet long and 1 foot wide; and one-ninth that of a battery composed of 20 plates, 3 feet long and 1 foot wide: hence if 20 plates, 1 foot square, be considered necessary for producing the required igniting effect, 2 plates, 3 feet long and 1 foot wide, would be nearly equal to the production of the same effect; but the cubic content of the box capable of holding 20 plates could scarcely be less than 2 feet, whereas that of one capable of holding 2 plates,

3 feet by 1 foot, need not be more than ½ a cubic foot, thus producing a great saving in the quantity of acid required for excitation,—a most important consideration in the field, where a momentary application only is required.

This principle evidently leads to much simplification of the apparatus for military purposes, as one pair of plates, 3 feet long and 1 foot wide, bent round in a cylindrical form, would be equivalent to the battery of 20 plates, 1 foot square, take up very little comparative space, and require still less acid. This is the form of one member of Professor Daniell's constant battery. The arrangement by spirals has also been found very efficient, and a single pair of plates bent in a zigzag form would constitute a powerful battery in a very small space. In regard to the conducting wires, it should be borne in mind that the principle on which ignition is produced is that of arresting a powerful electric current in part of its circuit by the intervention of a comparatively feeble conductor: it is right therefore that the body of the conductor should be of the best conducting substance, and the limited portion of it intended to be heated by arresting the current in its progress, of the worst conducting substance. These conditions are fulfilled in the usual combination of copper wire as the principal conductor, and platinum wire as the arresting or accumulating portion; but should any accident prevent the use of platinum, care must be observed in endeavouring to replace it by any other substance. By consulting the Table II. (vol. i. p. 371), any error will be avoided. It there appears that the conducting powers of platinum and iron are the same, and that the quantity of heat evolved in the passage of the electric current through each is the same: hence it is evident, that provided the diameters of the wires be the same also, the one metal may replace the other as the heating portion of the circuit. In either of these cases the conducting power is to that of copper as 1 to 5, whilst the heat evolved is as 5 to 1,—being reciprocally proportional to the conducting power. In tin and lead the conducting powers are lower, and the heat evolved greater than in iron and platinum, but their low melting points render them useless for this purpose. Zinc, though next to platinum and iron, is far inferior to them, and would also be rejected from its low melting point. Silver is equal to copper in conducting power, and therefore could not be applied; and gold being only one-third less, is also inapplicable:—should therefore the operator be forced to substitute any metal for platinum, he should use iron, and endeavour to reduce the finest wire he can obtain to the required diameter, or increase the intensity of his battery and the diameter of the conducting copper wire.

Several forms of Battery have been noted by Capt. Hutchinson under 'Electricity,' and the subject will be further resumed under 'Voltaic Battery;' but it may be observed that Mr. Thornthwaite is of opinion that intensity must be considered as well as quantity, and gives the preference to Mr. Smee's battery of silver and amalgamated zinc.

GEOGNOSY AND GEOLOGY.*—The actual meaning of these terms being, of the one, a knowledge of the earth, and of the other, a treatise or discussion tending to promote such knowledge, it is natural that they should have often been used to designate the same inquiries: at present, it is more usual to signify by the term Geognosy, a study of the nature, characteristic differences, modes of arrangement and combination, and distribution of rocks; and by Geology, a study of the phenomena (whether connected with the mineral, vegetable, or animal kingdom) of the formation and subsequent modification of those masses, stratified or unstratified, of mineral matter which constitute the crust of the earth. These two branches of inquiry are, however, so intimately connected with each other, that although it may

* By Major Portlock, R. E., F. R. S., F. G. S.

be possible to acquire a competent knowledge of the actual composition and general nature of rocks without inquiring into or seeking to know the laws which have regulated their formation, it is certainly impossible to acquire a sound and comprehensive view of the phenomena of formation, modification, and disturbance in that portion of the earth's crust which comes within the scope of observation, without having previously acquired a knowledge of the composition and qualities of the rocks or strata which compose it. In this brief sketch, therefore, of the science, those parts of each branch of inquiry will be combined together which are considered essential to the successful application of the theory in practice.

If we look at Geology in the widest sense of the term, it appears to us as a science intimately connected with the highest branches of physical research. The earth, as one of the planetary bodies revolving round the centre of our solar system, must, like all the other planets, be subject to the great laws by which they are retained in their orbits, and caused to revolve on their axes; it is, in short, only one member of a great whole, and in its density, its volume, and its mass, is in strict relation to all the other bodies of the system. The first formation, therefore, of the earth, or the manner in which it was probably condensed from nebulous matter, and reduced to the planetary form, may be considered a portion of Astronomical science. And if we leave this sublime inquiry, and enter upon the more practical investigation of the present state of the earth's surface, we are soon convinced that there is something more in the rocks and strata we discover than mere masses of stone, or heaps of gravel, sand, or mud, confusedly thrown together: we find, in fact, that these deposits have been the result of forces tending, according to the laws of nature, either to break up and remove or to deposit and consolidate in new forms the mineral strata, and our science is thus connected with the experimental sciences of Meteorology and Chemistry.

Nor is this all; for whilst we examine the mud and sands of our own coasts and seas, and find imbedded in them, or resting upon them, the relics of many living species of animals and plants, we cannot overlook the analogy in distribution and arrangement exhibited by the sandstones and clays of other epochs, and the wonderful fact that they too are associated with the relics of organic beings. It is here then that we learn the close connection of Geology with the natural sciences, and are taught to view that science, which may at first have appeared to us an humble investigation only of the circumstances of inert matter, in the lofty character of an expounder of the mysteries of organic creation.

Thus much has been said in order to impress upon the reader the philosophical importance and dignity of Geology; and that its practical importance is the result of its philosophical connection with the exact sciences will now be shewn.

Let it be here premised, that a science is practically valuable just in proportion as its laws have been discovered and studied. So long indeed as we are uncertain whether a known result has proceeded from a definite cause, we are unable to apply the fact or circumstance to the elucidation of other facts or circumstances; and so long as we are unacquainted with the properties of any substance under our examination, we cannot declare with certainty what share it may have had in the phenomena we have observed. This may be illustrated by a reference to gunpowder. Its explosive quality is the result of its composition, and we can only depend upon the results when we know that the compound has been accurately formed: to insure, therefore, certainty in our operations with it, we must take care that a proper standard of composition has been adhered to. In a similar manner we can only apply Geology as a practical science, when we have ascertained and made ourselves familiar with those facts which prove the first principles, on which it has been built up, to be correct and stable.

For example, were all the deposits we meet with, here rock and there sand, gravel,

and clay, mere arbitrary heaps which had never been brought under the controlling influences of organic or inorganic forces, we should be unable to use the one as an index to the history of the other, and the study of each individual deposit would end as it had begun, in itself alone.

But if it be proved that certain physical agencies have, according to fixed laws, been in operation from the earliest periods of our planet's history, and that they have either co-operated with, or acted upon, organic beings, so as to check, modify, or destroy, at successive times, the course of animal and vegetable life,—and if in the strata themselves we can find the fossilized relics of such successive races of organized beings, and be enabled to make the one a guide to the other,—how different is the result, as uncertainty now gives place to certainty, and a knowledge of the strata of one portion of the earth's crust becomes a clue to the investigation of those of any other. And it is upon this certainty, obtained by the collection and collocation of facts from all parts of the world, that Geology rests its claim on the attention of practical men; nor can it be necessary to urge other arguments as a motive to our brother Officers to study a science at once rich in facts of the highest interest, and capable of the most important practical applications: as briefly as possible, therefore, will be explained—

1st. Those theoretical deductions which, proceeding from the observation of facts, have resulted in the establishment of what are called geological formations.

2nd. The practical application of the theory.

In order to acquire a clear conception of geological phenomena, it is necessary to take a brief review—1st, of the various elementary substances which enter largely into the composition of the earth's crust, and of the fluids connected with it; and 2ndly, of the principal compounds formed by them.

Including most of the metals, there are more than fifty substances which, having as yet resisted the efforts of the chemist, still continue to our senses simple; of which sixteen only occur extensively amongst ordinary mineral compounds, whether fluid or solid. They are, *oxygen*, *hydrogen*, *azote* or *nitrogen*, *carbon*, *sulphur*, *chlorine*, *fluorine*, *phosphorus*, *silicium*, *aluminium*, *potassium*, *sodium*, *magnesium*, *calcium*, *iron*, and *manganese*, which, combined together in various ways, compose the greater portion of the earth's crust and of its liquid envelope.

The other elementary substances, though several of them, as bromine, iodine, and borine, are highly interesting, and some, as the metals are most important, do not constitute a portion of the whole sufficiently great to require a specific notice in this part of our subject.

The important offices of some of these substances are generally known; as for example, of hydrogen and oxygen in water,—of oxygen and nitrogen in air,—of carbon as a minute but very essential constituent of air,—of carbon again as a combustible substance in turf, wood, and coal,—of iron as the most useful of metals; but in addition to these well-known offices, they have others, little less essential and marked, to perform in the mineral constitution of the earth's surface, as it is by their combination with the principal metallic bases that the minerals of which its great bulk consists are formed: considering the elements in order, this first great fact will become evident.

Oxygen combines with silicium to form silica, of which it constitutes more than a half; but silica, either pure, or combined as an acid with metallic bases, has been estimated to form almost one-half of the solid crust of the terrestrial globe; and hence oxygen, in this one condition, is equivalent to a quarter of the ponderable matter of the earth's surface. But oxygen is also combined with aluminium to form alumina, an earth which is an essential constituent of certain minerals and rocks, the decomposition of which produces the beds of clay, so general throughout the world; and, when the quantity of mud or clay found in modern alluvium, and the beds of clay in more

ancient deposits, are considered, as well as the strata of mica and clay slate, of great thickness and extending over miles of the earth's surface, in all of which alumina is an essential ingredient, the several varieties of clay being essentially silicates of alumina proceeding from the decomposition of the felspar and mica of granite, gneiss, mica slate, and clay slate, the importance of alumina must be considered only second to that of silica; but of this earth, oxygen in weight forms nearly one-half.

Again, of carbonate of lime, the basis of limestone, a mineral constituting in many parts of the world mountain masses of many hundreds of feet thickness, oxygen forms also nearly one-half; so that if we add to these instances of its presence that of water, so abundant in the mineral as well as the vegetable and animal kingdoms, and of which it forms in weight eight-ninths, we may readily believe that of the whole crust of the earth, at least one-half is composed of this remarkable element.

Hydrogen, as a constituent of water, enters into the composition of many minerals and mineral strata, and forms a part of almost every organic substance.

Azote or *nitrogen*, as a constituent of the atmosphere, of most animal, and of several vegetable substances, is an important element, although it is scarcely appreciable in the mineral kingdom. Traces of this fundamental element of animal organization are, however, to be observed, in the form of ammonia, in those strata wherein were deposited the remains of animals, and such traces have been sometimes appealed to as a test of the former presence of animals in strata which now exhibit no fossil evidence of their existence; but however striking this exhibition of ammonia may be, it is subject to so many sources of uncertainty, as to be justly considered insufficient in deciding so obscure and difficult a question.

Carbon, the basis of coal, the base of carbonic acid, and the most considerable element of the solid parts of animals and vegetables, is one of the most important substances in nature; it forms nearly one-eighth part of carbonate of lime, and is therefore an essential constituent of the earth's crust.

Sulphur, a constituent of animal and vegetable substances, being exhaled in large quantities from volcanoes, either in a pure state or in combination with hydrogen, has evidently proceeded from some of the mineral substances with which they are connected. Sulphur is also visibly a part of the mineral kingdom, as it occurs in the sulphurets, and in sulphate of lime or gypsum; but as regards the sulphurets, its presence is often only secondary, being the consequence of the partial decomposition of the sulphuric acid of soluble sulphates. And here may be noticed the singular chain of composition and decomposition exhibited by this substance. In beds of shale, iron pyrites (bisulphuret of iron) is frequently very abundant, and when water gains access to it, there is a partial decomposition, some of the oxygen of the water combining with the sulphur to form sulphuric acid, which then combines with the iron, also oxydized from the water, to form sulphate of iron. This soluble salt is carried away by the filtering water, and when it comes in contact with animal or vegetable substances imbedded in the strata, is again decomposed, the oxygen going to the hydrogen and carbon of the organic bodies, and a sulphuret of iron being deposited in their tissues. The results of this process, as exhibited in fossil vegetables and in the organic portions of shells and fish, are sometimes very beautiful, and it may be doubted whether the succession of compositions and decompositions has yet been traced up to its first commencement in the more ancient geological strata.

Chlorine, as a constituent of chloride of sodium (common salt), takes part in the formation of those extensive beds of rock salt which occur in various geological formations. Chlorine forms nearly $\frac{7}{12}$ths of chloride of sodium, and is therefore another example of a gaseous body entering extensively into the composition of the earth's crust.

Fluorine, when combined with oxygen as fluoric acid, unites with lime to form

fluate of lime, or fluor spar, which is often associated with lead in vein-stones. It is also a constituent of mica and hornblende, but it may be considered important rather in a mineralogical than geological sense.

Phosphorus.—A constituent of phosphate of lime, a rather rare mineral as Apatite, in the mineral kingdom, but a most important one in the animal kingdom, as being the mineral portion of bone, the strength and stability of which depend upon it. It is also a constituent of many vegetables, and *from them enters into the animal structure.* Darwin mentions two curious secondary productions of phosphate of lime,—one at St. Paul's Islands, where the rocks are coated with it, the action of the spray on the dung of sea fowl having produced phosphoric acid, and at Ascension, where stalactites of the same mineral have been produced in a similar way.

Silicium or *Silicon*, the metallic basis of silica.—The important position this substance occupies has been shewn under 'Oxygen;' most of the minerals, exclusive of the carbonates and sulphates of lime, which form the earth's crust, appearing in the form either of silex or of silicates. The water of springs and wells always contains a little soluble silica: in mineral waters its quantity is sometimes more considerable, and associated with an alkaline carbonate, it occurs in the hot alkaline spring of Reikum, in Iceland, and in the boiling jets of the Geyser. These latter modes of occurrence, whilst they indicate the slow but continued destruction of the silicates of the mineral kingdom, give a useful hint as to the probable formation of much of the crystalline quartz in nature.

Aluminium, the metallic base of the earth alumina.—Alumina, as one of the principal constituents of clay, and of all those minerals and rocks from the decomposition of which it is produced, is, as shewn under 'Oxygen,' a most important portion of the earth's crust. It is also well known as one of the component parts of alum, a salt so extensively used in dyeing, which is a double sulphate of potash and alumina. The sulphate of alumina is formed naturally by the action of sulphuric acid, proceeding, as already stated, from the decomposition of iron pyrites (bisulphuret of iron) on the beds of clay or of shale in which that mineral is abundant. The sulphate of alumina being dissolved out, and separated by crystallization from the protosulphate of iron formed at the same time, is mixed with sulphate of potash, and the two combine to form the double salt alum. Alum-stone, a natural product of volcanic countries, also yields, by heating, this substance: it is abundant in the ancient crater of Solfatara, near Naples.

Potassium, the metallic base of the alkali potash.—Potash is a component of many minerals, especially of felspar (a well known constituent of granite and gneiss), of which it forms nearly $\frac{1}{6}$th part. Potash in this mineral is in the condition of a silicate, and it is from the decomposition of rocks containing felspar that the soil is provided with the potash necessary for the support of various plants. From the artificial destruction of these plants, the potash is obtained for use in the arts, and has therefore obtained the name of vegetable alkali from the source of its secondary production. It is the base of the important mineral compound, nitre or nitrate of potash, which will be further noticed.

Sodium, the metallic base of soda, an alkali which replaces potash in albite (soda felspar).—Soda has been called the mineral alkali, in contradistinction to potash, but such a mode of distinction is now known to be groundless. Carbonate of soda is obtained from kelp, or the ashes of calcined sea-weeds, and might therefore, as a secondary production, be also called vegetable. Soda is likewise found in all animal fluids, and the base itself is widely diffused in that most valuable salt, the chloride of sodium, or common salt. Nitrate of soda abounds in Peru.

Magnesium, the metallic base of the earth magnesia.—Magnesia, as a silicate, is a

component of many important minerals, especially of pyroxene or augite, of amphibole or hornblende, of steatite, and of serpentine. Of hornblende it forms $\frac{1}{8}$th part. It is also remarkable as a carbonate in dolomite, or magnesian limestone, a combination of the carbonates of lime and magnesia which is very extensively diffused in nature, and forms occasionally mountain masses. The effect of magnesia on vegetation is well known. As a carbonate, it would in itself perhaps be innocuous, but as it is liable to be decomposed and to form very soluble salts, it may be carried into the vegetable organism, and thereby prove injurious. As an alkaline earth it is dangerous from continuing so long in a caustic state.

Calcium, the metallic base of the earth lime which forms more than a half of carbonate of lime.—It is unnecessary to dwell on the vast importance of the latter mineral, both as an economical substance and as a constituent of the earth's crust; but lime is also found as a component of another valuable mineral—sulphate of lime, or gypsum, of which it forms about $\frac{1}{4}$th part. Gypsum occurs in extensive beds in more than one geological formation; in America in the primary or Silurian, in England and Ireland in the secondary, and along the Mediterranean in the tertiary strata, divisions which will be hereafter explained. Lime also enters into the composition of a great variety of minerals.

Iron.—The mere name of this metal must recall to memory the multitude of uses to which it is applied, and justify us in regarding it as one of the greatest gifts of creative intelligence to man. In addition, however, to its occurrence in a mineral state in our coal measures, as clay iron-stone, and also as spathic iron, both of which are carbonates of iron, in masses and in disseminated nodules as anhydrous and hydrated peroxide of iron, or red and brown hematite, in the magnetic oxide and in specular iron, or Elba iron,—minerals which as ores are smelted for iron,—it is found almost pure in masses of meteoric iron and in a vein traversing mica slate in North America. In combination as an oxide, it is extensively diffused, being found in small quantities in most minerals, and consequently in the soil of the earth's surface. It occurs in many springs, being dissolved as a protoxide by water charged with carbonic acid, and then again deposited as a peroxide, either at the bottom of marshes, as bog iron, or on the banks of the springs: but it is deserving of notice that this apparently simple operation is, in reality, compound; the tangled masses of this substance, so frequent in such situations, proving, on examination, to be the work of an infusorial animal,—the gaillonella ferruginea,—which thus interposes and reduces the mineral to an animal substance. In the colouring matter of the blood, of the hair, and of many other tissues, both animal and vegetable, this metal is also found, and its uses are not therefore limited to the great works of art,—the machinery of civilized social life,—but are traced also in the many charms which are shed over life itself, by the varied colours assumed, under the control of creative power, by the petals of the flower, the egg and feather of the bird, or the skin of man and other animals.

Manganese enters into the composition of a great number of minerals, though often in a very small quantity, forming, in such cases, their colouring matter. It is also found in the ashes of plants and the bones of animals. It is used in the arts; for preparing chlorine by the action of its peroxide on hydro-chloric acid, oxygen by the action of the same oxide on sulphuric acid, to render glass colourless by its oxidating action, and as a deutoxide to colour glass purple.

These then are the simple elementary substances which have been combined together in that portion of our globe which, by the long-continued action of meteoric agencies, has been reduced to a condition suited for the support of animal and vegetable organization. They will now be considered in the compounds which form the strata of the earth, and which we shall find also to be few; but is this surprising, when we reflect that a multitude of animal and vegetable substances, many of which

are possessed of the most opposite qualities,—some being alkalis, some acids, some poisons, some wholesome food,—have all been compounded of the four simple elements, carbon, oxygen, hydrogen, and azote? There is, however, one point deserving here especial notice, as bearing on the great question of the former condition of our globe; namely, that of the ponderable matter of the earth's crust, taking into consideration oxygen, hydrogen, and carbonic acid, ⅔rds have existed, or been capable of existing, in a gaseous state.

2. The minerals which enter into the composition of rocks, and of stratified beds, are few; namely,—quartz, felspar, mica, augite, hornblende, oxydulated iron, carbonate of lime, sulphate of lime, double carbonate of lime and magnesia or dolomite, chloride of sodium or rock salt, coal, and lignite. Many other minerals occur occasionally in rocks and sedimentary deposits, and impress upon them a consequent peculiarity, such as the garnet in mica schist, the tourmaline in some varieties of granite, flints in chalk and other calcareous formations, iron pyrites (bisulphuret of iron) and carbonate of iron in shales, crystallized carbon or the diamond amongst the gravel and other transported or alluvial matter along the Ghauts in India (especially at Golconda), as also in Borneo and in Brazil; but these, as well as the vast variety of minerals found in the basalts or lavas of ancient and the trachytic lavas of modern volcanoes, and those either associated with metallic ores or isolated in mineral veins, although replete with interest to the mineralogist, and often of great value to the carefully inquiring geologist, are insignificant as to quantity, when compared with those cited as the principal constituents of the earth's crust.

The composition of these minerals may be represented in a tabular form.

Species and Variety.	Silica.	Alumina.	Lime.	Magnesia.	Potash.	Soda.	Oxide of Iron.	Oxide of Manganese.	Carbonic Acid.	Sulphuric Acid.	Water.	Fluoric Acid.	Lithia.
Quartz (when pure)	100	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,
Felspar (green, of Siberia)	62·83	17·02	3·00	,,	13·00	,,	1·00	,,	,,	,,	,,	,,	,,
Do. (Carlsbad)	64·50	19·75	trace.	,,	11·50	,,	1·75	,,	,,	,,	0·75	,,	,,
Do. (soda or Albite, of Finbo)	70·48	18·45	0·55	,,	,,	10·50	,,	,,	,,	,,	,,	,,	,,
Do. (Albite, of Chesterfield)	70·68	19·80	0·23	,,	,,	9·06	,,	,,	,,	,,	,,	,,	,,
Mica, or talc-mica, (Zinnwald)	47·00	20·00	,,	,,	14·50	,,	15·50	1·75	,,	,,	,,	,,	,,
Do. (2nd Zinnwald variety)	46·23	14·14	,,	,,	4·90	,,	17·97	4·57	,,	,,	3·73		4·21
Do. lepidolite (granular or scaly mica)	50·35	28·30	,,	,,	9·04	,,	,,	1·23	,,	,,	5·20		5·49
Augite (green)	54·08	,,	23·47	11·49	,,	,,	10·02	0·61	,,	,,	,,	,,	,,
Do. (black)	53·36	,,	22·19	4·99	,,	,,	17·38	0·09	,,	,,	,,	,,	,,
Hornblende (green, Pargasite)	46·26	11·48	13·96	19·03	,,	,,	3·43	0·36	,,	,,	,,	1·60	,,
Do. (black)	45·69	12·18	13·85	18·79	,,	,,	7·32	0·22	,,	,,	,,	1·50	,,
Oxydulated iron	,,	,,	,,	,,	,,	,,	peroxide, 2 atoms; protoxide, 1 atom.	,,	,,	,,	,,	,,	,,
Carbonate of lime (when pure, as calcareous spar)	,,	,,	55·93	,,	,,	,,	,,	,,	43·58	,,	,,	,,	,,
Sulphate of lime (gypsum)	,,	,,	33·00	,,	,,	,,	,,	,,	,,	44·80	21·00	,,	,,
Do. (anhydrite)	,,	,,	41·75	,,	,,	muriate, 1·00	,,	,,	,,	55·00	,,	,,	,,
Dolomite (by Thomson)	,,	0·68	30·54	22·91	,,	,,	1·69	,,	48·22	,,	,,	,,	,,

may be considered a compound of sodium 40·5 and chlorine 59·5, or old view, 53·29 of soda and 46·71 of muriatic acid, but it is usually a small quantity of extraneous substances; the salt of Cheshire

Muriate of soda . . .	98·32
Muriate of magnesia . . .	0·02
Muriate of lime . . .	0·01
Sulphate of lime . . .	0·65
Undissolved matter . . .	1·00

Coal and lignite in like manner exhibit a great variety as to purity, and even as to the condition of their substance. Blind coal, culm, or anthracite, contains for example from 94 to 97 per cent. of carbon mixed only with mineral matter, as no bitumen has been developed in it, though traces of vegetables have been discovered even in anthracite: this therefore is a non-flaming coal, and yielding an intense heat, is particularly valuable for the lime-kiln and similar purposes. The Kilkenny coal of Ireland and the culm of Wales belong to this division. Newcastle coal is on the contrary a flaming or bituminous coal, consisting, in the best varieties, of carbon 84·99, hydrogen 3·23, oxygen 11·78, bitumen having been developed in its substance by the action of oxygen and hydrogen on a part of its carbon. Lignite still exhibits the structure of wood, and may be considered a fossil charcoal.

In looking at the Table, a substance will be observed, not named in the list of principal elementary substances, its quantity being small in the composition of rocks, namely, lithia, an alkali which has obtained its name from the Greek λίθειος, as being first derived from an earthy mineral. The metallic base lithium was obtained by Davy from the alkali; its equivalent is very low, 6·44, and its oxide has therefore a high saturating power. The discoverer of the alkali was Arfwedson, in 1818.

It is right also to draw attention to the variation of the quantities of elements in varieties of the same mineral, a fact constantly occurring in mineralogy, and explained by the chemical theories of equivalents and isomorphism. This latter doctrine is founded on observation, and means, that substances possessing the same elementary constitution may replace each other in a mineral, without disturbing its principal or characteristic qualities; for example, alumina is possessed of the same elementary constitution as peroxide of iron, namely, it consists of 2 of base to 3 of oxygen, and can thus replace it; and magnesia, possessing a constitution of 1 of base to 1 of oxygen, can replace the protoxide of iron. In green and black augite this is well exemplified by the proportions of the bases: as,

Green augite,—magnesia 11·49 + prot. iron 10·02 = 21·51
Black augite,—magnesia 4·99 + prot. iron 17·38 = 22·37;

and it is thus that the chemical composition may often vary, and yet the formula of composition be preserved.

The physical characters of these minerals it is difficult to convey fully to the mind by written description, and it is recommended to the student to obtain accurately named specimens. The following remarks may however be of use when combined with the subsequent description of rocks.

Quartz is well known both as rock-crystal, which is often called diamond, as Cornish diamond, Bristol diamond, Quebec diamond, although without the slightest relation to that mineral, and as common quartz. The prevalent colour is white: when pure it is either transparent or translucent; when impure it is commonly opaque. Its lustre is vitreous, inclining in some varieties to resinous. The streak is white.

Felspar.—Prevailing colour, white, sometimes grey, and in many granites and

syenites flesh red; transparent, translucent, or almost opaque; lustre, vitreous, inclining to pearly on the faces of cleavage.

By observing the tendency to a resinous lustre in quartz, and to a pearly lustre in felspar, these two minerals may generally be distinguished from each other without difficulty.

Mica.—Prevailing colour, white, grey, yellow, dark brown, or black; transparent and translucent, especially in thin laminæ; lustre, pearly; flexible and elastic when in laminæ, by which character it is distinguished from chlorite and talc. This remarkable mineral is at once recognized in granite, gneiss, and mica slate, by the brilliancy of its plates or laminæ.

Augite.—Colour varying from green or grey to brown and black; generally opaque; lustre, vitreous, inclining to resinous; brittle. This is a very common product of volcanic rocks.

Hornblende.—Prevalent colour, shades of green extending up to black; generally opaque; lustre, vitreous, inclining to pearly in light-coloured varieties. Brittle when isolated, but when massive it is frequently tough, and therefore difficultly frangible.

The two last-named minerals are reducible to the same chemical formula, as they are both bisilicates of lime and magnesia, in which a portion of the acid or silica is sometimes replaced by alumina, and a portion of the base by protoxide of iron, according to the law already noticed; but they afford an example of dimorphism, as the crystalline forms are different. Hornblende is an essential ingredient of syenite and greenstone, and occurs frequently in granite, gneiss, and other mountain rocks, and this general difference of geological position will naturally lead the inquirer to judge in most cases whether he is looking at the one or at the other; but as it is sometimes very difficult to determine whether a rock should or should not be classed with greenstone or with basalt, it is also sometimes difficult to distinguish between these two minerals. In general the species hornblende contains less lime than augite, and is also less fusible; but as might have been supposed from the similarity of their elementary constitution, it is possible, under certain conditions of heating and cooling, to change the external crystalline form of the one into that of the other,—a fact which has been used to explain the difference of their ordinary position.

Oxydulated Iron or *Magnetic Iron*, a compound, according to Berzelius, of 2 atoms of peroxide and 1 atom of protoxide of iron.—It is highly magnetic, and when massive, more so than any other ore of iron. Colour, iron-black; opaque; lustre, metallic. It forms extensive beds in Norway and Sweden: at Dannemora the beds are excavated to the day, the principal mine forming a chasm of one hundred and fifty feet broad, and five hundred feet deep. The amorphous masses of Siberia and the Hartz, which yield the most powerful natural magnets, may be associated with this species.

Carbonate of Lime, and also Double Carbonate of Lime and Magnesia.—The presence of carbonic acid can always be determined by the action of an acid and the consequent ebullition produced by the escape of the carbonic acid. This is the easiest and most certain method of detecting the various species of limestones.

Sulphate of Lime—distinguished from carbonate by not effervescing with acids; and from other minerals, whether in its fibrous or lamellar state, by its comparative softness.

Of salt, coal, and lignite, it is unnecessary to say more under this head.

We have now passed in review the more ordinary geognostic minerals, and are prepared to inquire under what combinations they are usually presented to our observation.

A survey of any extensive portion of the earth's surface will generally bring before us two distinct forms of mineral matter; the one, in which the mineral constituents

are combined together in distinct crystals, which to the eye exhibit no traces of any previous wear, and produce therefore crystalline rocks; the other, in which the constituents have undergone wear, are either mixed together confusedly or separated into distinct beds, but whether loosely aggregated or cemented together, betray the action of various meteoric and mechanical agencies, producing rocks, evidently of deposition, whether mechanical or chemical. To the first class belong—granites, syenites, greenstones, basalts, gneiss, many varieties of mica slate, granular limestone. To the second—sandstones, conglomerates, shales, clays, compact limestones; and if these forms were always so marked as in the examples cited, the divisions would be sufficient and satisfactory; but it is impossible to examine the rocks formerly called primary, without finding in some of them a condition closely approaching to the sedimentary, as for example, in the mica slate division, in which the clay slate varieties are sometimes little more than a highly indurated shale; or to look at true sedimentary rocks in the vicinity of ancient lavas without observing their change into forms which might place them in the crystalline division: for example, the lias shales of Portrush in Ireland have undergone this change to such an extent that they were at one time considered a portion of the basaltic field, and were only separated from it when the presence of ammonites of the lias had combined with their evident stratification to remove them to their proper place; the result of such observations having been the establishment of the metamorphic theory, which will be again referred to at a future stage of our subject.

In the preceding paragraph, allusion has been made to the occurrence of ammonites in the indurated, or more properly, metamorphosed shales of the lias of Portrush in Ireland. This mixture of the remains of organic bodies with ordinary mineral matter is no casual fact; it has been proved to occur in almost every portion of the globe, and has been traced through so extensive a series of strata, as to have necessarily connected the study of the animal and vegetable with that of the mineral kingdom. Nor has this study been without fruits, as it has not only shewn a varying geographical range of known types of organic beings at successive periods, but it has also brought to light new types which tend to prove a variation of the conditions of the earth's surface at successive epochs.

If now we combine the three modes of considering the earth's crust, we shall find that the one will illustrate the other, and that together they will enable us to form a reasonable history of the changes it has undergone. It is not, however, the aim of the geologist in such researches to go back to final causes, as he well knows that a science of observation can only trace the laws, or modes of action, agreeably to which they have been developed. He feels indeed a conviction impressed upon his mind, by a multitude of facts, of the necessity of a great first cause, but at the same time he is forced to acknowledge that the nature of that cause can only be learnt by a revelation made of itself by itself.

Returning, for example, to crystalline rocks: the existence of definite minerals combined together in crystalline forms is most readily explained by supposing that they were previously dissolved by a solvent; and Werner, therefore, discarding the theory that crystalline rocks were only a portion of the original mass of the earth cooled down, assumed that they had all been dissolved by a fluid menstruum, and subsequently precipitated in the form of beds; the whole superficial crust, which does not exceed on an average in thickness $\frac{1}{1000}$th part of the earth's radius, being therefore of secondary origin, as the primeval mass had been acted upon by a solvent, which, in his opinion, was an aqueous one.

The principal reason of the disciples of Werner for adhering to this opinion, was the difficulty of drawing any line of demarcation between strata manifestly of aqueous

deposition, and those in which no traces of that deposition can now be observed; and it was even urged that beds containing fossils were so closely associated with the crystalline, that they could not with any reason be separated from each other. Let the theory of Sir J. Hall be applied on true metamorphic principles, and this difficulty disappears. The accumulation, through a vast series of ages, of detritic matter, proceeding from the decomposition and wear of original rocks, may have concealed all traces of these rocks, but yet that accumulation must have had a beginning, and it is very probable a beginning anterior to the creation of any organic beings; and if so, it would not be unreasonable to suppose that portions of crystalline rocks, formed by the gradual cooling of a once fluid mass, may have been removed by the wearing agents, and deposited in beds below the primeval ocean, and that these beds, acted upon under the pressure of the superincumbent fluid by the great remaining heat of the earth's mass, might exhibit that return to a homogeneous crystalline arrangement which the observation of a vast number of similar facts has shewn to occur when sedimentary beds have been acted on by ancient or modern lavas. The metamorphic theory therefore removes Werner's great objection to the application of recent analogies in explaining the condition of crystalline rocks, and we are enabled to state that crystalline rocks may either be the result of direct igneous action, producing a species of fluidity, as in lavas, and probably in some granites and porphyries; or of the indirect action of heat acting for a long period and under pressure, on sedimentary deposits, and tending to promote or facilitate the re-arrangement of the mineral particles into a crystalline or semi-crystalline condition, as has been the case in the crystalline schists, and in some other strata the physical condition of which has been altered, although the existence of organic bodies still demonstrates their former sedimentary character. It is by the careful examination of recent and still recurring natural phenomena that these truths have been made manifest; and it is by the continuance of such examination that any remaining difficulties must be removed. It has for example, in another work, been urged, that in the great basaltic deposit of Ireland all the beds are probably not eruptive, but, on the contrary, that some are metamorphic, just in the same manner as in the vicinity of modern volcanoes,—of Vesuvius, for example, where beds of tufa and of ashes are observed covered by streams of lava. The change produced on mineral beds by contact with highly heated matter has indeed now been demonstrated, almost with mathematical precision; and though it is very difficult to decide its exact limitation, we can never satisfactorily study the strata of the earth without referring to it. And if the metamorphic theory thus aids us in determining the varying mineral conditions of the earth's crust, the organic remains still visibly imbedded in many of its beds demonstrate that changes equally striking have taken place in the successive organic inhabitants of its surface; in short, that there have been animal and vegetable as well as mineral epochs. The beautiful combination of facts on which Palæontology now rests, as one of the most sure bases of geological science, can only be fully appreciated by careful study; but in this brief memoir it must be assumed to have been studied, and this result arrived at, namely, that at those various epochs of change on the surface of our globe, when the mineral strata were affected deeply and widely, shales and slates, sandstones and conglomerates, limestones, &c., being formed, some in one place, some in another, great modifications also took place in organic beings. If this conclusion be true, and it rests on facts observed over a large portion of the earth, it must be admitted that the evidence of the epochs of mineral change ought to coincide with that of the epochs of organic change, and hence that the study of the one may be made to assist that of the other.

This remarkable deduction has in a few years elevated Geology almost to the

rank of an exact science, and, when combined, as it will be, with the more extensive study of the operations of the great forces which still act and always have acted on the earth's strata, such as magnetism, or electro-magnetism, will render it so practically exact, that not only may the probability (under any conditions of strata) of discovering certain useful products be at once stated, but the more abstract and obscure questions of mineral veins and of the distribution of metals be also solved on sound principles.

On the combined testimony of all these forms of facts, it may then be assumed, that as mineral matter can now in volcanoes be brought into such a state of semi-fluidity as is sufficient to allow of the crystallization of minerals, so may it at former epochs have undergone a similar fusion, and hence that there is a reason why truly igneous rocks may at such epochs have existed, and have been brought nearer to the surface, or even erupted;—that, in a similar manner, the changes produced by slow igneous action under great pressure, have been observed in strata contiguous to modern and ancient lavas, and consequently may be fairly admitted to have occurred in strata contiguous to other igneous rocks, giving rise to schistose crystalline rocks in all their varieties, and more or less modifying the structure of many other sedimentary deposits;—and finally, that changes in the combinations of organic beings, having been by extensive observations proved to have occurred at successive epochs, a knowledge of the particular group of animals or plants connected with the mineral strata of one portion of the globe becomes a clue to determine the relation of such strata with those of any other portion in which the organic constituents have been previously studied. The certainty thus attained constitutes the value of geology as a practical science; and though there is much yet to do, in order to remove mere varieties from the lists of characteristic fossils by determining the actual limits of species, it must be admitted that some of the modern applications of the science have been most striking. A general representation of the combined theories of igneous rocks, metamorphic rocks, and fossiliferous deposits, is given in the ideal diagrams, the first of which I extract from Cotta, Plate I. fig. 1; and fig. 2 from the Transactions of the Geological Society of France.

The preceding remarks will account for the great change which has taken place in the opinions of geologists as to the true character and relation of the rocks once called primary, and will explain the difficulty of forming any simple natural arrangement of rocks which cannot by fossils be associated together in a historical series. The presence of granite veins in the adjacent schists, the frequent disturbance of the schists at or near the points of contact, and the change of structure so often manifest, are sufficient reasons for supposing that the respective rocks which exercised a mutual action on each other, must at the time have been in a condition suited for its display: the granite, for example, in a fluid or semi-fluid state to admit of the penetration by it of the schists, and hence that it had acquired its present consolidation subsequently, at least, to the existence of the materials of the schists in their present positions. Granite, therefore, as a rock, must in many instances, if not in all, be considered secondary to the schists; and there is even strong reason for believing with Keilhau that it is often merely the result of a still more perfect change of the schists by which the traces of stratification have been entirely obliterated. The similarity of composition in many of these rocks, although from difference of crystalline structure appearing so different, is shewn by the following Table, which is compiled from the calculations of De la Beche and Phillips, and from my own analysis.

Elementary Substance.	Granite: Quartz 2 parts, Felspar 2 parts, Mica 1 part.	Binary Granite: Quartz 2 parts, Felspar 3 parts.	Syenite: Quartz 1 part, Felspar 1 part, Hornblende 1 pt.	Quartz Rock,* coloured by Chlorite.	Greenstone* type of Mica Schist.	Mica Schist,* passing into Clay Slate.
Silica	74·84	75·1	69·91	48·81	51·49	52·45
Alumina	12·80	10·9	10·37	12·58	13·59	12·01
Potash	7·48	9·8	4·55	2·89	5·01	3·82
Magnesia	0·99	0·0	4·86			
Lime	0·37	0·5	6·26	8·81	10·20	7·72
Oxide of iron	1·93	0·4	2·69	25·64	18·47	17·92
Oxide of manganese	0·12	0·0	0·07	,,	,,	,,
Fluoric acid	0·21	0·0	0·65	,,	,,	,,
Water	Not estimated.	Not estimated.	Not estimated.	1·27	1·24	6·08

The three columns marked with asterisks are from my own analysis; and the words formerly attached to them may here with advantage be quoted, as extending their application from greenstones to granites.

"Between rocks closely resembling clay slates with laminar structure and shining appearance, and rocks by external appearance associated with greenstones, there would appear to be little affinity; and yet the composition, as regards the principal constituents, is, as may be seen, by no means so various as might have been supposed; the silica, the alumina, the iron, and the lime, not differing more than is often found to be the case in varieties of the same mineral. A very small alteration or addition of substance is therefore sufficient to place a rock in such a condition as may lead to a most important ultimate change; and viewed in this light, the varieties observable in extensive schist districts possess a very high geological interest."

This simplicity of composition of the crystalline schists further assists in connecting them with the comparatively unchanged deposits of sedimentary matter; and as the decomposition of such rocks leads constantly to the formation of new beds of sand and of mud, so also at any time may the resumption of the forces which have modified the ancient beds, and induced in them a crystalline arrangement, produce a similar result in the recent beds. This view has led to the abandonment of the term primary in its original sense, and to the admission of a possibility of finding crystalline rocks, both stratified and unstratified, in the formations of all ages. It is not, however, to be supposed that though the peculiar modification of rocks called metamorphic is now generally admitted, the mode in which it has been effected is equally assented to: on the contrary, there are several modes, each of which has its supporters. In our own country, the long-continued action of highly heated masses acting under pressure, which may be considered the full development of Hutton's original idea, has been adopted as the theoretical explanation of the phenomena of crystalline schists, and the peculiar term 'hypogene' has been proposed by Lyell to express the conditions of metamorphism. In Norway, Keilhau has promulgated a totally different theory, and supported it by numerous facts, the result of a careful examination of the crystalline rocks of Sweden and Norway. His opinion is, that the metamorphism of rocks is independent of any igneous action, and is the result of a peculiar action, analogous to the galvanic, taking place at the line of contact between different rocks or strata; and though it is true that the proximate cause of such an action cannot be demonstrated by a direct reference to chemical experiments, such an objection may also be as strongly urged against the hypogene igneous theory, as the alternations of change through an endless variety of species, visible in every great schistose formation,

cannot be explained by direct experiments, and seem often contrary to them; some of the most altered being separated from the supposed focus of change by others far less altered.

But though the theory of change deduced from facts be yet uncertain, the facts themselves may be admitted, and some of those detailed by Keilhau are peculiarly instructive and interesting. (See Plate II. figs. 4, 5.) Fig. 5 represents a granite vein in the rock called locally ‘ Norite,’ a mixture of felspar, quartz, hornblende, hypersthene, and some mica, having a rudely parallel arrangement. Fig. 4, hornblendic layers in mica schist, Island of Högöe. Without, therefore, asserting that the theory itself of change is established, the crystalline rocks may be temporarily arranged in series, according as the change appears to tend towards some final resulting rock; for example, in the crystalline schists towards either granite or syenite, as by such an arrangement the usual order of facts will be equally well represented, whatever view may be taken of their cause.

Massive Crystalline Rocks.		Stratified Crystalline Rocks, and more simple Strata connected with them.	
Granite. . . .	Quartz, felspar, mica.	Gneiss.	Quartz, felspar, mica.
		Mica schist.	Quartz and mica.
		Clay slate.	Crystals become so small that the mass appears homogeneous, though still glistening.
Pegmatite (graphic granite) . . .	Quartz, felspar.	. . . .	. . . .
Protogyn . . .	Quartz, felspar, talc.	Talc gneiss.	Quartz, felspar, talc.
		Talc slate.	Quartz and talc.
Syenite	Quartz, felspar, hornblende.	Syenite schist.	Quartz, felspar, hornblende.
Greenstone . .	Felspar, hornblende.	Greenstone schist.	Felspar, hornblende.
		Hornblende schist.	Principally hornblende.
Hypersthene rock	Felspar, hypersthene.	Hypersthene schist.	Felspar, hypersthene.
Porphyry . . .	Granites, syenites, and other massive rocks exhibit frequently a porphyritic structure, that is, by the development of isolated crystals in the mass.	Hornstone porphyry. Felspar porphyry. Clay porphyry.	These and many other rocks, including the various crystalline schists, exhibit occasionally the porphyritic character.
Basalt	Felspar, augite. The mixture so intimate, that the separate crystals can scarcely be distinguished: a distinctly volcanic product, still occurring in recent lavas.		Looking at the character of some of the beds associated with the basalt, it is scarcely possible to doubt that many of them are metamorphic, over which at various epochs the basalt has flown, and that similar changes have taken place in them as in other metamorphic strata. Using them as an illustration of the crystalline schists, it may also be suspected that streams of still more ancient lava exist in the close-grained greenstones associated in regular stratification with them.
Dolerite (basaltic greenstone) . .	Felspar, augite. The crystals distinct, closely associated with ordinary basalt.	. . . .	
Ophite	Porphyritic serpentine or green porphyry.		

Massive Crystalline Rocks.		Stratified Crystalline Rocks, and more simple Strata connected with them.	
Melaphyr, or augite porphyry .	Felspar, augite. Rendered porphyritic by isolated crystals of both felspar and augite.	. . . . . .	This rock also indicates in part an original schistose arrangement.
Trachyte, or trapp porphyry . .	Felspar base, with crystals of glassy felspar; the ancient lava of Auvergne and of the Rhine.	. . . . . .	As yet I am not aware of any detailed account of truly metamorphic rocks connected with these.
Andesite . . .	So called from the Andes. The trachytes occur also in the basaltic district of Ireland, so that these two forms of lava are associated together just as the most recent lavas and basalt are.		
Domite	More earthy trachyte.		
Lava, modern . .	Including basalts similar to those of more ancient volcanoes.		
Leucite lava . .	Leucite and augite—the former prevailing; this mixture being also rendered porphyritic by isolated crystals of augite and glassy felspar.		

In conclusion, as regards these rocks, it may be stated that difference of age, even in the granites, can be distinctly determined in many cases by the rocks which they have either upheaved or broken through: for example, the protogyn, or talc granite of the Alps, has lifted up strata of the tertiary epoch, and must therefore be considered even more recent than the rocks of that comparatively late date. The granite of Cornwall has affected the killas (a slate of that district), and is therefore subsequent in age to the Silurian, in which epoch it is now probable this slate may be classed. The syenites also of the North of Ireland are, from similar reasons, posterior to the Silurian series; and, tracing their action in the formation of porphyritic beds in the old red sandstone, subsequent also to that formation. The granites of Wicklow were probably associated with older rocks, as also those of Down and Cavan; whilst a portion of the basalts of Ireland are, from similar reasons, more recent than the chalk.

But in addition to this stratigraphical mode of determining their age, Leonhard endeavours to draw a distinction between old and new granites from certain peculiar minerals they respectively contain; the tourmaline, for example, which he considers a characteristic mineral of modern granites, and the garnet. If this mode of comparison should be proved correct by more extended observation, the mica schist of Antrim, which is so closely connected with the basaltic rocks of that county, may really be metamorphic of the secondary epoch or of an age not much prior to the chalk. The recent observations of Sir R. Murchison, tending to shew that the direction in which mountain chains have been raised has a relation to the minerals and ores developed in their mineral veins or lodes, have also an important bearing on this subject, and may hereafter assist in clearing away the difficulties which yet obscure the history of crystalline rocks.

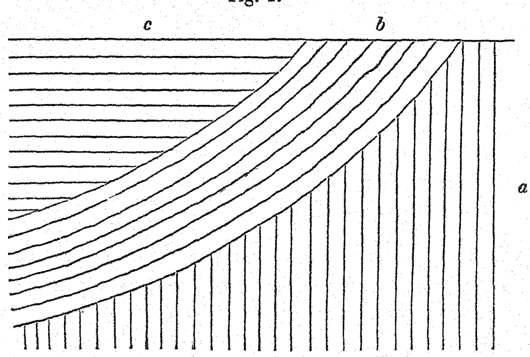
PHENOMENA OF ROCKS.

Before proceeding to the consideration of formations, the relative order of which can now be determined by the study of the natural history of each, that is, by the fossils contained or buried in the successive strata, it is desirable to notice those phenomena, or accidents of strata, which have materially aided in first establishing the fact of their succession, and must still be resorted to in all doubtful cases of position.

STRATIFICATION.

Many rocks exhibit a lamellar arrangement throughout their mass, which induces a schistose or slaty structure, and this is sometimes related to the greater planes of supposed deposition, sometimes to a plane intersecting that of deposition, and called cleavage. In the first case the structure may be connected with original deposition; in the second it may be due to subsequent or metamorphic modifications. In all cases where rocks are observed to consist of distinct layers, lying one over the other, and each having a considerable extension, they are said to be stratified. If this stratification had been observed to be uniform in all places, it might be assumed that deposition had gone on regularly and without disturbance; but as it has been ascertained that the stratification is often very irregular, both in the thickness of the beds and in their position and direction, it must be admitted that some interfering cause has disturbed and modified their deposition. Again, if to a succession of beds having a considerable inclination, called dip, to the horizon, succeed other beds, perfectly or nearly horizontal, it is reasonably concluded that the first beds must have acquired their tilted-up arrangement before the deposition of the undisturbed horizontal beds, and thus an epoch of disturbance or separation is established; the terms conformable and unconformable being applied to the strata as they preserve or lose their parallelism.

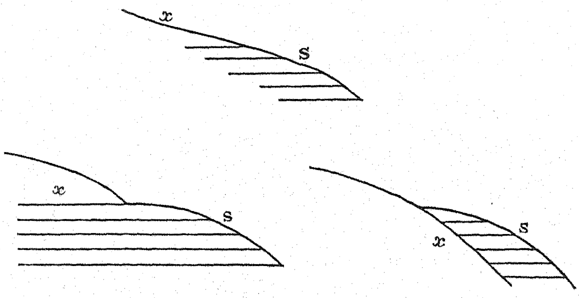
Fig. 1.



Thus *b* is unconformable to *a*, and *c* is unconformable to *b*, whilst the beds of *a*, *b*, and *c*, are conformable within themselves.

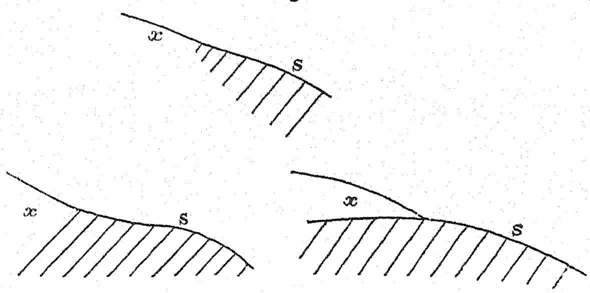
As the true position of every bed or stratum as a part of a system must have been originally determined by a reference to the actual order of superposition, although its fossils may afterwards have been applied to clear up obscurities even in stratification, the great importance of accurately studying the stratification is evident, and this is sometimes not without difficulty, as will be seen in the following examples.

Fig. 2.



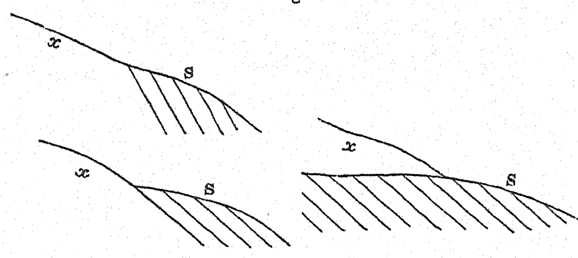
In fig. 2 the portion x may be found either to overlie or to underlie the stratified beds when sufficiently opened to show the connection.

Fig. 3.



In fig. 3, though x overlies the stratified beds, it may be found either conformable or unconformable to them.

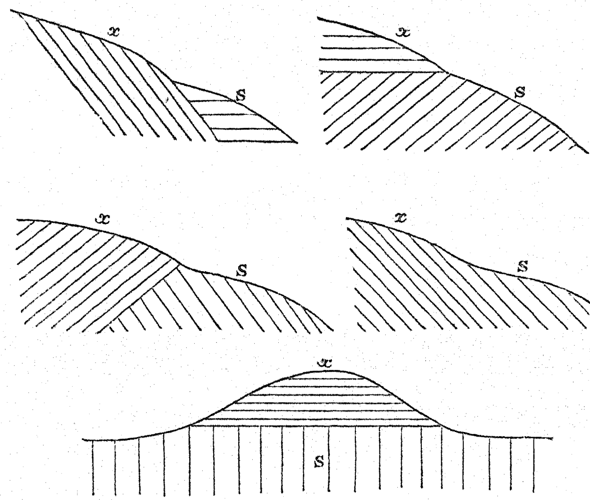
Fig. 4.



In fig. 4, x may either underlie or overlie the stratified beds.

x has in these cases been represented as itself unstratified; it may, however, be also stratified, and then the following example will shew the possible results.

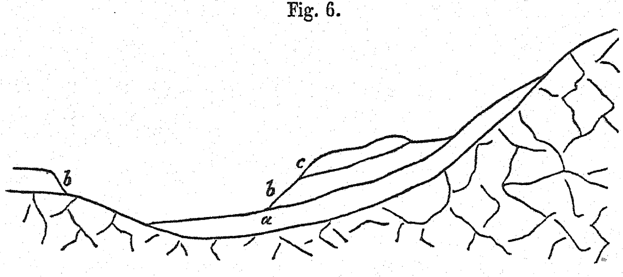
Fig. 5.



In all of which x is unconformable to S, excepting in the fourth, where it is conformable to S, although possibly of a different mineral character.

It will be observed from these examples how much caution is required in determining the exact conditions of stratification, and in not too hastily deciding that a rock is older or younger than another from its *apparent* position; and further this is shewn more distinctly in

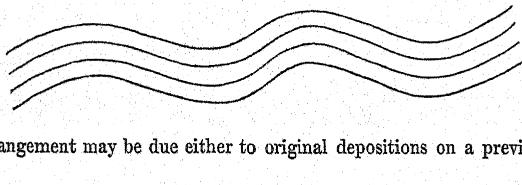
Fig. 6.



where *a*, though generally lower in natural position as it is older in geological age than *b*, rises up from below it to a higher level; and again *b*, though underlaid by *a* at one point, rests itself directly on the massive rock at another, and might be, even from a mere comparison of levels, supposed to underlie the elevated portion of *a*.

Strata are frequently undulating on the large scale, though, when examined at any one point, they may appear to have a uniform inclination.

Fig. 7.



This arrangement may be due either to original depositions on a previously modi-

fied surface, or to gentle movements of the underlying mass prior to the consolidation of the overlying strata. The crest or ridge transverse to the highest point of each bend, as here shewn in section, forms an anticlinal ridge nearly in the direction of the line of strike, and a line carried in a similar direction along the hollow is the synclinal line.

FLEXURES AND CONTORTIONS OF STRATA.

The case of gentle undulations above noted is simple, but the flexures and contortions of strata are often exhibited on a grand scale, and with appearances of the most striking kind. See Plate II. figs. 7, 8, Plate III. fig. 16.

To illustrate such flexures and contortions of strata, an experiment was made by Sir James Hall. Several layers of clay were placed under a weight, and their opposite ends having been pressed by considerable force more closely together, it was found on the removal of the weight that the layers were curved and folded so as to resemble, in miniature, the natural strata. Other similar illustrations have been proposed, but it may be remarked that in all of them the materials acted upon are supposed to be flexible; whereas in the crystalline schists, contortions are exhibited in strata now of such great hardness that they could not be supposed capable of assuming such forms without having been shattered, or at least penetrated by numerous cracks at the bends. That such internal movements have often taken place, even in the most indurated strata, cannot be doubted; and that one stratum has sometimes been forced over another, the surfaces being broken up and formed into a breccia, seems evident from the brecciated structure of some strata; but in the present case we can scarcely doubt that the now highly indurated and crystalline strata were, at one period, soft and pliable. To render the evidence of this fact as tangible as possible, I have selected the illustrations, not from gneiss, mica slate, &c., in which they have long been known to occur, but from rocks of which the sedimentary character cannot be doubted, although they have subsequently assumed a high state of induration.

In the Carpathian chain, the metamorphic rocks including gneiss, mica schist, talc schist, clay slate, associated with syenite and porphyry, are succeeded by an extensive formation of sandstone. Intercalated with this rock, in several places, are beds of limestone, which, from their fossils (ammonites, &c.), have been allotted either to the green sand, the whole formation therefore belonging to the cretaceous system, or to a connecting link between the oolite and the chalk. In either case it is a formation comparatively recent, and as it comprises clays and limestones with the sandstone, it is very favorable for studying the mechanical effects of pressure, as well as those of metamorphism. For example, it is stated that the schistose clays had in some places become silicious slates, with occasional veins of cinnabar, the marls had been converted into jasperoid rocks, and the sandstones either into quartz rock or into highly quartzose grit full of pyrites, whilst the mechanical changes during this metamorphic action have been equally striking, as exhibited in Plate II. figs. 7, 8. The first example is met in crossing the mountains Lomnitzer Berg from Mizun to Angelow, where the Carpathian sandstone, there associated with thin beds of limestone, exhibits the singular flexures represented; the second at Dolhopole, on the road from Stebnicz to Hryniowa, where the sandstone is beautifully contorted; and many similar examples might be cited from the memoir of the late M. Lill, on the Carpathian Mountains, (Mémoires de la Société Géologique de la France, tom. i.)

To these I have added, Plate II. fig. 9, an example from the marls of the new red sandstone of the county of Derry, in which the alternating beds of hard calcareous grit exhibit some very curious contortions; and another, Plate II. fig. 10, from Lyell,

of tertiary beds in Sicily, where thin beds of solid gypsum are interstratified with bent and undulating gypseous marls, the solid beds having been broken into detached fragments, still preserving their sharp edges, while the continuity of the more pliable and ductile marls has not been interrupted.

In endeavouring to explain such phenomena, and to render them available for scientific research, it is desirable not to lay too great a stress on one cause of change to the exclusion of others. There can, for instance, be no doubt that many minor contortions, and some flexures in strata, may be the result of their original deposition on banks and amidst the eddies of currents; but we cannot suppose such flexures as those in the Iselten Alp, where Lyell observes that "curves of calcareous shale are seen from 1000 to 1500 feet in height, in which the beds sometimes plunge down vertically for a depth of 1000 feet and more, before they bend round again," to be due to such a cause, and must look upon them as striking evidences of disturbance. Let us then examine their bearing on this question, as connected with the Carpathians. M. Bouè, in his analysis of the subject, states that the mountains of Hungary and Transylvania indicate upheaving, accompanied by fractures in four directions, viz. from S. W. to N. E., from N. W. to S. E., from W. S. W. to E. N. E., from S. S. W. to N. N. E., and fractures without upheavings, or faults, generally from N. to S. or from E. to W. Amongst these directions, the first two, S. W. to N. E. and N. W. to S. E., are alone common to the crystalline schists and to the secondary rocks, shewing that movements had taken place affecting both these classes of rocks; whereas the directions W. S. W. to E. N. E., and S. S. W. to N. N. E., affect the schists alone, and were therefore antecedent to the formation of the overlying secondary rocks of the country. It is deserving of notice also that a similar result as to the latter directions may be observed in the mica schist district of the North of Ireland, where the prevailing strike of the schistose strata is W. S. W. and E. N. E., whilst the secondary sandstones are seen to rest undisturbed upon their edges. (See Plate III. figs. 11, 12, 18.) Again, M. Bouè observes, that in the Carpathian chain the absence of the lower secondary strata prevents the determination of the actual age of the crystalline schists, though they are satisfactorily shewn to be older than a portion of the secondaries, and M. Bouè even considers that the epoch of disturbance may be placed before the oolitic period, if not before that of the new red sandstone, the chains of Western Hungary being only the prolongation of the Alps and the Jura, or oolitic strata, as well as of a portion of the red sandstone overlying unconformably the more ancient Alpine strata.

The upheaving in a direction from S. E. to N. W., and in that from S. W. to N. E., has given rise to numerous contortions in the Carpathian strata, extending even to the beds of molasse deposited at their base; so that this movement or disturbance must be at least posterior to the lower tertiary strata, of which that deposit is a part. In a similar manner M. Bouè traces the probable *geological* dates of the other lines of disturbance, and shews also their probable connection with the appearance (eruption in his opinion) of certain igneous rocks; namely, of syenites in the secondary period, of metalliferous porphyry in the lower tertiary, and of trachyte in the upper tertiary. I have dwelt on this topic because it illustrates forcibly the mutual dependence of geological facts, and the mode of reasoning which has been so successfully applied in deducing from the disturbances of stratification an indication of the age of strata.

CLEAVAGE.

In studying stratification, or the successive deposition of strata, a source of difficulty is often experienced by the appearance of other lines of division, which are called cleavage. In rocks containing fossils, beds of flints or layers of pebbles, or in thinly alternating strata of very different composition, such as sandstone, limestone,

shale, this can rarely be a source of difficulty; but in cases where the deposit is uniform for a great thickness, and constituted of massive beds, it is often so, and it is then necessary to use considerable caution in deciding which line of division is that of stratification. As an aid towards investigating this subject, it is desirable to bear in mind the following remarks.

Stratification, as the result of successive deposition, may be often expected to exhibit a somewhat irregular or undulating surface, but still to possess considerable lateral extension. Cleavage, on the contrary, whether it be the result of a polarizing action during the deposition of a bed, or of forces acting subsequently to deposition, may be expected to exhibit surfaces more even but more frequently interrupted; and a little attention to this distinction will often enable the observer to decide by detecting the abrupt termination of a face of cleavage. Cleavage, again, is due to general laws, and is principally developed in directions having a definite connection with the axis of the earth: where then it is exhibited on the large scale, the strike of its planes will have a direction approximating to N. and S. or to E. and W.; and this circumstance will often enable an observer, by comparing them with the ordinary direction of the planes of stratification through a district, to remove doubts in an obscure case: in North Wales the mean strike is E. 45° N., though it is sometimes E. 45° S.; but in this instance the strike of the bedding is nearly the same, whilst the dip of the cleavage is generally greater than that of the bedding. In stratified deposits, the direction of the planes of stratification, by the outcropping in cliffs on one side and the slope of the beds on the other, impresses a character on the surface of the country, whereas cleavage, by its abruptness and generally high angle, rarely does so to the same extent, although the actual direction of the great ridges is due to the cause which has produced cleavage, and is often not co-incident with the strike of the bedding: on the other hand, the great lines or ridges of strata are often cut through by cross cleavage, and a passage given to rivers across them. Deep narrow dells are therefore often the result of cross cleavage, whilst wide and open valleys are more frequently the result of stratification, their direction being modified by elevation.

The smaller description of cleavage which I have alluded to as probably resulting from a polarizing action during the deposition of strata is very remarkable in slates, which are frequently fissile in directions not parallel but transverse to the stratification; but it may also be observed in sandstones, and also in the more recent detritic (diluvial) deposits. See for the first, Plate III. fig. 13, and Plate III. fig. 14 for the other cases. The very excellent observations of Mr. Sharpe, who has followed out the researches of Sedgwick, Phillips, and Darwin, on the effects produced on fossils by the expansion or disturbance of the strata, and their relation to the planes of cleavage, prove the general connection of cleavage with the great elevating forces.

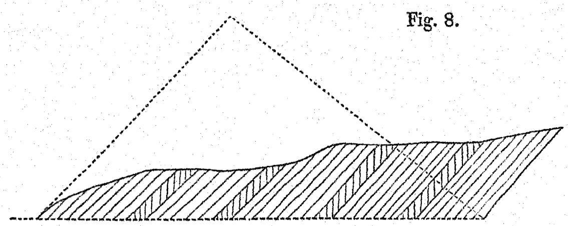
DENUDATION AND WEAR.

The term denudation, though strictly meaning the act of laying bare, is geologically applied to the result of that operation; so that a valley is said to be a valley of denudation when it is the result of the removal of a large mass of superincumbent strata, and the consequent denudation of the underlying rock. Though in reality this is only one form of the general problem of wear, it deserves, as it has obtained, especial attention, as being peculiarly calculated to awaken a lofty conception of the vast operations of the most simple natural causes, and to connect together their workings at the most distant epochs. If it were asked what has been the amount of denudation, the reply should be with Lyell, that it may be measured by the whole mass of our stratified deposits, as they have all been detached and removed from their

primeval positions. If the question were, "At what time did it commence, and how often has it been repeated?"—that its commencement must at least have been anterior to the deposition of the crystalline schists of the earliest epoch, and that it has been repeated during every successive epoch of the earth's history. Such considerations as these will enable the observer to form a just estimate of the magnitude of the phenomena before him, and will relieve him from that hesitation to admit their possibility which is the consequence of a cramped perception of the forces which produced them. In no other science is this power of philosophic generalization so important as in geology, as the observer is constantly called upon to carry his mind forward from the contemplation of some very simple fact to that of a grand result, which he is at first, perhaps, disinclined to admit, or even unable to comprehend, as connected with it. In the Isle of Wight, a bridge may be seen thrown over a small stream, some 10 or 12 feet wide, and formed into *two arches*, with a pier in the centre: now can it be doubted that the builder of this little epitome of a bridge would have felt it difficult to conceive as possible the construction of some of the mighty works of the same kind which have of late days been executed?—and so it is with the geologist; he must not let his knowledge of the small cramp his perception of the great.

In considering the denudation or wear of the crystalline schists, we meet the solution of a difficulty which led even Playfair into error. That profound philosopher, in discussing the probable thickness of the known portion of the earth's crust, assumed the apparent succession of outcropping strata as a sufficient indication of it. For example, in a mica schist district an unbroken series of strata may be traced, dipping at an angle of 30° or 35° for probably 50 or 60 miles; and if it were assumed, as by Playfair, that all these beds were originally deposited one upon the other in a horizontal position, and subsequently elevated by a disturbing force, we should be able to deduce from them a very considerable thickness. In No. 8

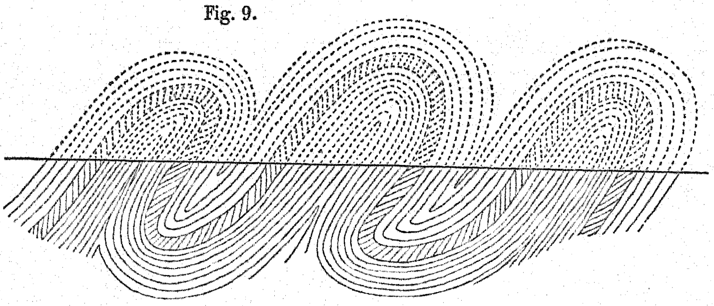
Fig. 8.



we suppose a section of the strata visible for 30 miles, in which the dip is 30°; and if they had been originally horizontal, the total thickness would be 30 sin. 30°, or 15 miles, and consequently the edge of each stratum must have been raised that height above the horizontal plane. Had the dip been 45°, a very usual one in the crystalline schists, the thickness would have been 21 miles, and the rise of the stratum edge the same. That the dip of strata is often partly due to original deposition on banks is undoubted, but there can also be little doubt that in this description of strata it is principally due to subsequent disturbance, which is strongly supported by the frequency of contorted strata in all districts of gneiss or mica schist. Whoever has carefully examined such districts must have been struck by the repeated alternations of certain sets of strata, such as quartz slate, thick beds of quartz with micaceous specks, granitiform gneiss, mica schist passing into gneiss, mica schist passing into clay slate, layers and beds of granular limestone, &c.; which, if all considered independent beds, would imply an extraordinary amount of deposition, and a multitude

of variations in the forces producing it, without any great disturbance, followed by the exhibition of some great and controlling force, capable of modifying the whole mass through a thickness of 30 miles, disturbing and elevating it at the same time; whereas the application of the theory of lateral pressure, which corresponds to the undulating movement of the earthquake, explains the phenomenon in a more simple way, as it represents these alternations to be the foldings of the strata in contortions, many of which are still visible, whilst others have been truncated by denudation, in the manner shewn in No. 9, the surface having been further modified, by subsequent wear and the removal of the softer strata, into mountain and valley.

Fig. 9.



Contorted Strata, removed, above the line, by denudation.

To render both classes of inclined and undulating strata as clear as possible, a section of the strata of the district of Vassy, in France, by M. Cornuel, (Mém. Soc. Géo. tom. iv.), is given in Plate III. fig. 15, in which, undulating beds, rich in iron ore, are seen to dip into the hollows previously worn in a portion of the oolitic strata, the dips in the iron beds having been subsequently filled with ferruginous sand. The whole of these beds are supposed by M. Cornuel to be anterior to the chalk, and they afford a very interesting example of denudation at that epoch. The form of undulating beds seems also to have prevailed during the carboniferous period, and the dipping strata have sometimes been so perfectly truncated by denudation, as to exhibit on the surface of the soil a horizontal plane. In the shales also of this formation, numerous examples may be found of wear, prior to the deposition of the overlying beds, so striking, that the mind is led at once to trace out the current which had produced them.

In Plate III. fig. 16 is a portion of the section of Dr. Lusser, taken in the Alps from St. Gothard to Asti on the Zugersee. In it the author marks out by dotted lines the supposed original continuity of the strata, the contortions of which are exhibited on a magnificent scale. These strata, although greatly changed by metamorphic action, are, in the author's opinion, continuous with those containing nummulites, and therefore not older than the upper secondary or lower tertiary: they are, as usual, in immediate connection with the crystalline schists, especially gneiss; and, as in them, it seems probable that some modification, whether from heat or other cause, must have preceded their disturbance, so as to endue them with sufficient tenacity to bear such contortions. In Plate III. fig. 17, an example is given of the deep denudation of the ordinary stratified deposits by currents or streams, unaccompanied by any great movement of disturbance. In Plate III. fig. 18, the mica schist is covered unconformably by new red sandstone, the two positions of the new red being in part probably due to disturbance. In fig. 12, the strata are shewn unconformably to the schists below; whilst, in fig. 11, the schists are quite denuded.

These examples are sufficient to prepare the observer for the vast amount of denu-

dation he will find displayed before him. It has gone on at all periods, and wherever one formation is laid bare by the removal of the overlying strata, evidences of its previous wear may be discovered, and this is even manifest in parts of the same formation; as for example, the tertiary sandstone of Corfu has been exposed to considerable wear prior to the deposition of the overlying blue clay, as is rendered manifest by the partial removal of the latter at the brick establishment of the Engineer Department at San Pantaleone, and the consequent exposure of the worn surface of the sandstone.

FAULTS.

The preceding phenomena have implied lateral movements and pressure, accompanied or followed by extensive denudation or wear. The present are the result of vertical movements, by which whole masses of strata, having been dislocated, have either slid down or been forced up, the same strata appearing thus repeated at a higher or lower level. See Plate IV. figs. 19, 20, 25; fig. 25 being a curious example, in which long tuberous-like deposits of iron ore have been affected by a fault and thrown down with the strata. In this case, then, the retaining force is lateral, and the moving force vertical, though probably sometimes resulting from the lateral pressure; and it is also highly probable, from the frequency of faults in all shale districts, that one cause at least of their occurrence is the shrinking of the mass, and that another is similar to that of land-slips. Fig. 20 is an example of such repeated faults, and their great importance to the coal miner, as well as the trouble they sometimes occasion him, are too well known to be here further enlarged upon, though they will again be noticed in the more practical part of this essay. See also Plate VI. fig. 34.

Although in itself great and striking, the actual amount of the vertical disturbance, as exhibited in faults, is small compared with the lateral, as displayed in contortions. In the Newcastle coal district, the upward or downward movement has amounted to nearly 1000 feet, so that the surface must have been originally affected to that extent, portions having either risen or sunk 1000 feet above or below the rest, although these projections or inequalities have been subsequently removed by denudation, and their former existence only discovered by studying the internal structure of the underlying strata. On every side, then, and at every level, whether we look at the varied surface of our earth as it now exists, and as it is now exposed to the incessant wear of rains, of torrents, of rivers, and of seas,—or seek for information within the deep recesses of the excavated mine, we find the same tale narrated, of continued disturbance and wear on the one hand, and of renewed formation on the other.

ANALOGY OF MODERN AND ANCIENT SEA CLIFFS, SEA BEACHES, GLACIERS, AND ICEBERGS.

So long as the deposition of the worn materials of the earth's original crust is unaccompanied by any evidence of the existence of air-breathing animals, or of plants, it is not to be expected that traces of that description of action which depends on a partial exposure of the surface above the level of the sea should be discovered. The vast beds of sandstone and conglomerate which prevail at certain geological epochs, indicate extensive wear and equally extensive deposition; but if taken alone, their analogous type would be sought in the accumulations of sand and gravel which now constitute submarine banks. The extent of the known sea banks would be sufficient in every respect to support and confirm such an analogy; for example, the banks of Newfoundland and the Bahama bank may be cited; and when it is considered that soundings of only moderate depth are obtained on these banks in the midst of the ocean, they may be fairly considered as analogous

to and commensurate with any of the more ancient banks which now constitute our beds of conglomerate or of sandstone. Nor in this comparative view should we lose sight of a useful practical hint which it suggests, namely, that as ancient conglomerates were the result of gradual accumulation, a proof of which is afforded by the alternations of sand and gravel which they exhibit, so are our modern banks in course of formation by the continued action of marine currents, combined with floating fields and bergs of ice, which convey with them the detritus of the regions whence they have come. In the hydrographic instructions issued to Captain Beechey, by the Admiralty, prior to the voyage of the *Sulphur*, it was wisely enjoined that the deep sea lead should be cast at convenient periods, even where no shoal was either known or suspected to exist; and should such a rule be extended to all her Majesty's ships of war, much valuable information might be expected to be derived, as data for determining the progress and changes of such deposits. Every time the lead touches the bottom, a point of comparison is obtained, and a datum for future investigation secured: and when a shoal is first discovered, preceding voyagers ought not always to be blamed because it was before unknown, as it is at least probable that in their time it had not been raised within the reach of ordinary soundings. If it were in our power to examine the internal constitution of sea banks, the occurrence here and there of the trunk of a water-logged tree, or of the hard fruits even of many plants, would not surprise us; but if we found beds of lignite or fossil wood, we should be obliged to admit that the bank had either been exposed to the air, and supported a growth of air-breathing plants, or at least had been formed in some shallow ancient estuary, adjacent to rivers whose banks had been clothed with trees: in a similar manner, the occurrence of fragments of anthracite in ancient rocks,—though proving that other parts of the earth at the time of their formation supported a growth of plants,—does not prove that such rocks had also been exposed; but the existence of beds, either of lignite or of coal, in a formation, proves that its strata had either been covered with plants or were contiguous to other parts of the earth then covered with them. Such evidence does exist in the ancient beds of anthracite and bituminous coal of the carboniferous and other strata, and in the lignites of the still more recent tertiaries; and as it thus appears evident that at a very remote geological epoch, some portion of the earth's surface had already emerged from beneath the water, traces might be expected to be found of that description of wear which, from the surges of the ocean beating on the shore, gives rise to our sea cliffs and our gravelly or sandy beaches: and if we further admit with Leonhard that the dark colour of some varieties of mica schist is due to carbon, and seek a terrestrial vegetable origin of that carbon, this condition of a partial exposure of the earth's surface would be carried back to a period antecedent to the earliest known fossiliferous strata, as there are certainly crystalline schists, including mica slate, subjacent to such strata.

Without, however, referring to such obscure indications of vegetable life and the existence of dry land, it is sufficient to rest at the great epochs when large deposits of carbonaceous matter, such as the coal of North America, of Australia, and of Europe, remove all doubt upon the subject; and for the present purpose it is sufficient to confine the inquiry to the latter. The old red sandstone which underlies the coal strata may be often seen to penetrate into recesses of the mica schist, in districts where the two are in contact. The character of the wear of the crystalline rocks, and the nature of the fragments existing in the old red sandstone conglomerates, shew that the former had sometimes attained their metamorphic condition prior to the deposition of the latter. The broken and rugged edges of the mica schist are in accordance with the natural wear of such a rock; but let us ascend to the coal series in which the beds of shale are more fitted to display the progress of wear, whilst

the presence of deep beds of coal manifests, that prior to their formation or deposition, forests of tropical plants, and therefore dry land, had existed in their vicinity. It is not easy to trace the cliffs or sea boundaries of these ancient periods, as most of the strata have again been submerged and covered by more recent strata; but as the existence of large pebbles of mica schist in the conglomerate which was formed in its ancient bays or recesses proves that a sea then beat against it, so may some of the greater faults of the carboniferous strata have been due, as before suggested, to ancient land-slips; and as deep precipitous banks are also not uncommon in this formation, the sea may have hollowed out the space which now is a lake, as in the case of Lough Erne, in Ireland. This latter example is also rich with evidence of an ancient sea bottom, as there may be seen on the shore a limestone covered with projecting corals, now exposed by the removal, from denudation, of the shale above it.* Whoever has noticed the manner in which the sea bottom in a warm climate is thus covered over by corallines (for example that of the Mediterranean), must at once perceive the force of this analogy. Indications of such shore wear may be doubtless acquired at every geological epoch; but after the deposition and consolidation of the chalk, it becomes more apparent, as the strata deposited subsequent to it were less extensive and more local. Mr. Lyell gives several examples of inland chalk cliffs which occur in Normandy, but none can be more striking than the curved escarpment of chalk which bounds the plain of Dungiven, in Derry, the tertiary clays with their marine shells occurring below it, and demonstrating in the most striking manner the existence of a former sea bed, at levels now from elevation varying up to 200 feet above the present sea, and that at a time when the sea cliff was, as now, chalk.

Plate IV.—Fig. 23 exhibits an example of this peculiar evidence of geological analogy; and fig. 24 another equally striking, namely, the occurrence of successive ancient sea beaches at elevations far above the present sea level. The wear of the ancient, and now inland cliffs, of the chalk, as also that of the white limestone of the Morea and of Sicily, took place during the deposition of the beds subsequent in date and now called tertiary, and it often exhibits a succession of cliffs at different levels, corresponding to so many successive pauses in the elevating forces. In some cases, the base of the ancient cliff is occupied by ancient mud banks, and in others, portions of a former sea beach may yet be found. Our subject may here be so far anticipated as to state, that in the strata called tertiary, the first decided † approximation to the existing order of things may be noticed in the occurrence of the remains of organic beings, identical with those still living in our seas, as also in the similarity of the erupted basaltic and trachytic lavas of that period with those of existing volcanoes. We seem therefore in them to be entering on the history of the earth, as it now is; and as we advance further into the light of recent day, new evidences of continued change are met with in the occurrence of sea beaches of still more modern date, although now far removed from the present action of the sea. Mr. Smith, of Jordan Hill, an indefatigable observer of this class of geological phenomena, has pointed out the existence of ancient sea beaches in Gibraltar, as he had previously done in Scotland and Ireland. In the latter country, Mr. Bryce and myself had also pointed out examples of the temporary rest of the ocean at points of the earth's surface, in the North of Ireland, now far removed from its action; and still more

* See Plate IV. figs. 21 and 22, for an illustration of this curious phenomenon, taken from 'Observations Géologiques sur le Jura Soleurois,' par A. Gressly.

† The term 'decided' is used, as Professor E. Forbes has shewn that there is reason to believe that at least one annelide is common to the chalk and to the existing epoch. Nummulites are common to the chalk and tertiary, so that this fact would connect more closely the chalk and tertiary deposits, by carrying into the former an existing type of organic life.

recently much valuable information of the same kind has been derived from an examination by our brother Officer, Captain James, of the gravel beds of the South of Ireland, his inquiries having been subsequently extended and perfected by the Members of the Government Survey, now under the sole direction of Sir H. De la Beche.

In the cave of Uddevalla, in Sweden, additional and still more striking evidence of this change of level was long since noticed in the existence of cirrhipeda adhering to its walls, the same as those which now attach themselves to the rocks of the sea shore; and we are thus, both by the evidence of mechanical wear and of organic relics, carried back step by step to ages beyond the reach of historic records, although bearing within them the means of identification with the present, and when the organic links of identity are lost, we can still trace in mechanical effects the working of similar causes up to the remotest epoch,—an epoch so remote, that Mr. Lyell has estimated even a small fraction of the time evolved, namely, that during which the comparatively recent deposits of the Missisippi have been formed, and the wear of its valley effected, at many thousand years. Some doubt may exist as to the strict validity of the reasonings of Mr. Lyell in this particular case, and another example may therefore be well cited, in which the enormous wear effected during the last pause of elevation may well prepare us to comprehend that of former epochs,—I allude to the present condition of Portland Island, cut off from the main land by the undermining of its more solid strata, and the removal of the underlying blue clay of the lias. At present, the Chesil Bank, an accumulation of sand and gravel, forms a natural breakwater, and lessens, though it does not stop, the progress of wear; but should another slight elevation bring up the blue clay nearer to the water's edge, the wear would advance again with rapidity, and the island once removed, the Chesil Bank itself would speedily be destroyed, and the sea advance upon the main land. The consideration of this case is of much practical value. The wear of Portland Island is comparatively diminished, because the dip of the beds is such as to carry the subjacent lias clay to a depth beyond the action of the moving wave, and to reduce the wear to that of the more solid rock: the Chesil Bank has been formed because the remaining portion of solid rock projecting forward checks the force of the current, and causes the deposition of the pebbles moving with it. The pebbles of the bank protect the subjacent clay from further wear, and thus the general tendency is to preserve a tottering equilibrium, which the slightest change will destroy. I have dwelt on this, because a renewal of elevation would here lead to renewed destruction; whereas if the elevation be supposed to bring up a solid stratum, it would stop such destruction, and such must have been the varying results of elevation at all geological epochs.

In the cases of ancient sea beaches and retired cliffs, elevation has, at least for a period, stopped extensive wear, by bringing up and opposing to the efforts of the sea a firmer rock. Depression may also produce the same effect, by removing from the action of the sea a soft stratum; and in speaking of Portland, it is right to observe that the depression of the blue clay beyond the action of the waves is probably the result of such a movement. In examining any coast, therefore, with a view to judge of its probable permanency, the following particulars should be especially noticed: 1st, the nature of the shingle or gravel, as shewing the direction of prevailing currents; 2ndly, the prevailing and most powerful winds; 3rdly, position and character of any barrier sheltering from the prevailing winds; 4thly, position and character of any barrier opposed to the prevailing current.

There can be no doubt that some of these modifying causes may even yet be traced in the ancient or raised beaches of former epochs, and equally little doubt that many such beaches have been swept away by the alteration of level, whether

of elevation or depression, having favored the work of denudation; and in any practical examination of our existing beaches all such causes must be considered. By the action of prevailing currents, the shingle is brought to the spot, and if checked by any barrier in that direction, forms a bank like the Chesil Bank, being gradually forced up by the waves impelled upon it by the prevailing winds. In protecting, therefore, a coast, the accumulation of shingle must be effected by a barrier transverse to the line of current, bearing in mind that the movement of the shingle is by a succession of steps, obliquely upwards by the force of the impelling wave, and nearly perpendicularly downwards by the force of gravity. And further, to bring the processes of wear and formation to an equilibrium, it is necessary to keep the forces producing them in a similar state, as the alteration of any one must lead to a change in the others. At present, for example, the Isle of Wight forms a barrier of protection to much of the opposite main land; and every thing which tends to preserve its outline unchanged, has an equal tendency to keep the wear of the opposite shore within assignable limits.

The importance of this subject is, it is hoped, a sufficient reason for the length at which it has been treated. Similar vestiges of ancient river as well as lake wear may also be cited: of the former, an example is given, Plate VI. fig. 30, in which the former bed of the river Burnthollet appears to have been 10 feet higher than its present course, as shewn by the remarkable masses of rock still remaining to attest its ancient wear: of the latter, the parallel roads of Glenroy, so often quoted, may be again cited here. These roads are ancient shelves or beaches, formed at the margin of a former lake, and at levels corresponding to its successive depressions. The highest is 1250 feet above the sea, the next about 1000, and the third 50 feet lower. Mr. Lyell remarks, that "among other proofs that the parallel roads have really been formed along the margin of a sheet of water, it may be mentioned, that wherever an isolated hill rises in the middle of the glen above the level of any particular shelf, a corresponding shelf is seen at the same level, passing round the hill, as would have happened if it had once formed an island in a lake." (Plate VI. fig. 31.) The great lakes of America exhibit similar lake beaches at various elevations above their present surface; the absence of marine shells concurring with other circumstances to remove them from the list either of ordinary marine beaches or of sea banks. The parallel roads of Glenroy will soon be tested in the most careful manner, to determine whether the opposite beaches are really on the same level.

But in addition to these forms of gravel deposits, the researches of Agassiz have opened to the geologist another in the effects of ancient glaciers. It has been long known that these vast accumulations of snow, in Alpine valleys, are in motion, proceeding from the higher valleys, where they are formed, to the lower, where they are gradually melted; the portion cut off or melted at the lower end being replaced by a new mass added at the upper end. It is unnecessary to discuss the various theories of this motion,—the fact is undeniable. In moving along, the glacier carries with it the fragments of rock which have fallen from the precipices above and formed upon it lines of deposit, to which the name of moraine has been given. M. Agassiz distinguishes three varieties,—lateral, in which the moraine borders the valley of the glacier, resting either on its surface, or between it and the side of the valley;—medial, in which the moraine is formed of a long line of débris stretching down the course of the valley like a riband on the surface of the glacier;—terminal, in which the moraine is seen at the lower or terminal end of the glacier. These forms of gravel deposit, interesting as regards the history of the glacier itself, become still more so when they are used as a clue to the explanation of gravel deposits, now no longer connected with glaciers.

It will be readily conceived that any considerable variation in the temperature of

the air must produce a similar variation in the amount of snow and ice, and consequently lead to an augmentation or to a diminution, as the case may be, in the glaciers resulting from them. That within very recent times, the variation has been towards an excess of cold, is shewn by the inquiries of M. Venetz on the variations of the temperature of the Swiss Alps; but if compared with still more ancient epochs, the evidence is in favor of a rise of temperature. M. Venetz establishes the first of these positions by a reference to both historical monuments and documents, which prove that some of the Alpine passes, now scarcely practicable, were then the ordinary lines of communication.

In the archives of the Commune de Bagnes, M. Rivaz found a record of a legal process between that commune and the commune of Liddes, relative to the possession of a forest then on the territory of Bagnes, which has since disappeared and been replaced by a glacier, now entirely cutting off the communication.

Many other examples are cited of the extension of the glaciers within the last 200 years; but such extension is small when compared with the vast extension they appear once to have attained. The evidence of former extension cannot be sought in historical evidence, as it passes beyond its period; but it may be found in the existence of ancient moraines, for, as M. Agassiz observes,—" we shall be forced to admit that many moraines, far distant from existing glaciers, must have been formed at the most remote periods, if not anterior to the creation of man." The careful examination of the deposits, which he thinks may be classed with moraines, has led M. Agassiz to trace, assisted by other phenomena of glacial action, the former existence of glaciers in countries now far removed, by their comparatively elevated temperature, from the sphere of their production; and M. Agassiz has thus brought the British Islands within the sphere of ancient glacial action.

Such inquiries and reasonings lead to the belief that there was a period of intense cold, when ice and snow were spread over a large portion of the northern hemisphere; and if on the lands of that frozen epoch, the glacier descended, as it now does in Spitzbergen, to the sea, icebergs must have been also formed, and the sea covered with them and floating sheet ice. Glaciers were the carriers on land of those fragments which formed ancient moraines;—icebergs and floes were the carriers on sea of those vast fragments which now as 'erratics' are dotted here and there along the course of the then marine current, just as the modern floe or iceberg now leaves at the bottom of the ocean, where it grounds and melts, the fragments of rocks it has carried along with it. Perhaps no one will now admit the operation of glaciers, in the extended sense of Agassiz; but it is in this manner that the careful examination of every recent phenomenon fits us for the discovery and appreciation of the operations of nature at the remotest epoch, and we are enabled by the application of the scale afforded us by new facts to measure the magnitude of the old.

PETRIFACTION—ORGANIC REMAINS.

In the preceding sections, allusion has occasionally been made to fossils, or the remains of organic beings, found in the ancient strata of the earth; and it is now the place to inquire more particularly what bearing the existence of such relics has upon the science, and what insight it affords us into the past history of the earth. In this, as in every geological inquiry, the object should be to reason from such definite data as the present course of natural events affords us, and to frame our theory from the results of our examination, not as was the custom with ancient geognists, to form a speculative opinion, and afterwards search for data to support it. In investigating, therefore, the laws which regulated ancient organic existences, it is necessary to study the laws which are now in operation upon those still existing. Here it is seen, as

shewn by Professor Edward Forbes, that the influences of climate, so marked upon land animals and vegetables, were much modified in marine animals by depth of water; and that it is necessary to study and take into account this peculiar element in the comparisons we make, whether between the existing marine animals of the present day at distant regions, or between the extinct animals of former epochs. On this most important view of the subject, M. A. Gressly has also, at an antecedent period (1837) published, in his Geological Observations on the Jura, some interesting remarks, an abstract of which will best explain the correct principles he advocates.

Taking as a rule the careful horizontal, as well as vertical, examination of the extension of each deposit, various modifications may be observed, in which peculiarities in the petrographic constitution of the strata, as well as in the palæontological character of the fossils, occur, and which are subject to peculiar and little varying laws. Two principles are deduced from these considerations.

1st. That a peculiar petrographic constitution in a stratum will be accompanied by a peculiar palæontological assemblage of fossils.

2nd. That such a palæontological assemblage excludes the genera and species frequent in strata of a different petrographic constitution.

If by chance it should happen that certain genera and species peculiar to one form of mineral stratum be found in another, it is a constant rule that the individuals of such genera and species are much more rare, much less developed and less distinctly characterized, than in that to which they properly belong. And further, it may be deduced, that where the petrographic (and geognostic) characters of a stratum are the best developed, so also are its fossils better preserved, and both as regards genera and species most developed and best characterized; and on the other hand, where the petrographic and geognostic characters appear mixed or uncertain, so also are the fossils obscure, rare, imperfectly developed, and badly preserved.

The modifications, petrographic and palæontological, which a stratum exhibits in its horizontal extension, depend on those variations in position and circumstances which so powerfully influence the arrangement of the genera and species now living in our existing ocean; or, in other words, in the distribution of fossils, and in the corresponding combination of petrographic and geognostic characters, may be discovered the laws of organic association and the conditions of existence which now rule in the submarine world.

In this manner a deposit may be considered a shore deposit, an ordinary shallow sea deposit, or a deep sea deposit, and in each case a peculiar combination of organic bodies should combine with the petrographic constitution to characterize it. And applying these principles to the rocks of the Jura, M. Gressly considers that the sedimentary deposits announce by their structure two distinct forms of origin,—

a. A purely mechanical one, in which they were formed in the midst of an agitated sea; as for example, rocks of a brecciated or rudely oolitic character.

b. An origin, partly chemical, in a quiet sea; as for example, marls, marly and compact limestones, either with a homogeneous paste, or with a paste finely oolitic, in which the grains are, as it were, fused into the paste.

These two types, variously modified according to their littoral or pelagic station, constitute distinct stratigraphic forms, and are accompanied by equally distinct and characteristic palæontological combinations. Rocks, for example, of a brecciated or of a rudely oolitic character, constitute the coralline type. They characterize a littoral or shallow water deposit, and include only fossils characteristic of coral banks, being composed principally of fixed corals, with a massive or branched stem capable of resisting the shock of the waves, and corresponding to the living genera agaricia, astrea, oculina, caryophyllea, &c., which now form in intertro-

pical seas the coral banks and reefs so dangerous to ships; the corals being accompanied by other organic beings which usually inhabit coral reefs, and appear to delight in continually agitated waters, being provided with a suitable organization; some being firmly attached to the rocks, and others possessing a highly elastic structure, which, yielding at once to the impulse of the wave, brings back the animal unhurt to its former position, when the shock has passed away. Amongst these occur the crinoids, with their long, elastic and flexible stem,—the more solid echinoderms, with either globular or flattened shells and strong plates and spines, such as the genera cidaris, diadema, and clypeaster,—whilst the spatangi, with thin shells and delicate spines, are almost entirely wanting. Amongst the mollusca, whether acephalous or gasteropoda, those genera abound which, like the oyster and spondylus, have firm bases of attachment which render them secure; or, like the perforating genera arca, saxicava, venerupis, can remove themselves by self-formed cavities from injury; or, like the genera trichites, chama, perna, are by the weight of their shells made secure; or, like the pecten, lima and terebratula, are preserved by the elasticity either of their shell or of their ligament of attachment; or, as in the genera turbo, trochus, nerinea, patella, &c., by the solidity of their shell or by adhesion to the rocks. This adaptation to the circumstances of the deposit influences the occurrence of all other bodies, and it may be assumed, as a very important and almost universal character in all organisms of the coralline type, that their shell or crust is massive, and marked by ribs, striæ, spines, knobs, and other peculiarities, which, whilst they doubtless added to their fitness for opposing the contingencies of their peculiar location, now afford so many valuable characters for studying them as inhabitants of an ocean long since passed away.

Deposits which may be called shingle, being the result of the more active wear of the waves, are often intimately connected with coral banks, but also accompany and link together all the petrographic forms of deposit. They possess few zoological peculiarities, borrowing, as it were, the characters of the several deposits with which they are connected by receiving from them the fragments of their various organisms, which are gradually, as they are carried along, worn down, passing through an oolitic state into an impalpable paste. Muddy deposits, such as marls, compact and subcompact limestones, together with sands and sandstones, constitute another important class, and exhibit a totally different zoological assemblage. The corals are of spongy and encrusting genera, and generally without apparent base. Crinoids are rare, scattered about, and generally of unattached genera. The echinida are less rare, particularly the true echini and their congeners. The spatangi abound in muddy and sub-sandy deposits. Of the asterida, the genera asterias and saccocoma are characteristic of muddy deposits, and of fine sands and gravel. Of the acephalous mollusca, the genera which abound are, solen, pholadomya, myopsis, pinna, tellina, mytilus, modiolus, corbula, isocardium, cucullea, and amongst the ostracea, especially gryphea, and exogyra. In the gasteropoda may be noted, rostellaria, pterocera, natica, turritella, fasciolaria; and amongst the cephalopoda, the genera nautilus, ammonites, belemnites, being either rare or abundant, according to the variations in the form of the deposit. Fish with pavement-like teeth are very characteristic of these mud deposits, and reptiles are especially abundant in the upper Jurasic beds, though locally rather than generally distributed. They prevail in what may be deemed muddy shore deposits. A general and constant character of all zoological assemblages in muddy deposits, is that the prevailing genera and species are provided with shells or coverings not fitted to withstand the wear of transport, being smooth and thin; and in those genera which possess a thick shell, the tissue is nearly non-elastic and easily disintegrates. It may be also stated, as distinctive of muddy bottoms, that the genera are more

frequently free than attached, even the stems of pentacrini not exhibiting strong roots, having been probably fixed by fibrillæ or simply immersed at their base in the mud.

The sub-pelagic and pelagic forms of muddy deposits, though corresponding to the littoral form in their petrographic conditions, are distinguished from it by zoological peculiarities.

The deep sea or pelagic deposits are very uniformly constituted, homogeneous, regularly stratified in continuous and often massive beds, except where modified or disturbed by the action either of currents or of elevating forces. In these deposits, large spaces are often deficient in organic bodies, or contain only their débris, together with those spongy and fibrous corals which are supposed to inhabit the waters of great depths; and where cephalopoda abound, the species differ from those which inhabit muddy shore deposits. M. Gressly sums up in these important deductions:

1. Each class or form of deposit presents characters, petrographic, geognostic, and zoological, peculiar to itself, and distinct from those of any other class or form of deposit, although of the same geological epoch.

2. That the same class or form of deposit, as regards its petrographic and geognostic condition, exhibits very analogous zoological characters in each successive geological formation in which it occurs.

These laws are of great interest, and highly important in the application of zoological characters to the determining of geological formations; but in applying them it is necessary to take into account every disturbing or modifying influence, in order to separate, in any stratum, those organisms which are peculiar to and must have found a fitting habitus in it, from those which have only been brought into it from other situations by currents, storms, &c. In the muddy sub-pelagic bottom of the channel of Corfu, in the Ionian Islands, many of the thin-crusted and silky-spined spatangidæ are found, together with nuculæ, tellinæ, corbulæ, and other organisms fitted for such a habitus; but these are combined with abundant exuviæ of other organisms foreign to such a habitus,—as the valves of strongly-ribbed cardia, pectens, &c. In the one case, the shells, &c., are generally perfect or alive; in the other, more frequently separated and injured; and when in bivalves they are still connected, they are often found wide open and even twisted. These remarks will doubtless recall to the geologist many similar cases in the deposits of ancient worlds; and as a striking example, I may cite the condition of the fossils described by Mr. Phillips in his work on Palæozoic Fossils. They are singularly broken and defaced, which, combined with the general detritic character of the formation called old red sandstone, part of the Devonian of Murchison, and the identity of many of the most characteristic fossils with those of preceding strata, supports the idea that this deposit was under the influence of currents, and therefore exhibits the organisms fitted for other classes of deposit rather than for its own, such effects being different from the distortions effected by the internal movements of disturbed strata. The following rule, therefore, should be added to the other two.

3. In every petrographic class of deposit two sets of organisms may be expected to occur: the one suited to the habitus afforded by its geognostic position, and therefore the truly characteristic organisms of that class of deposit, or those which should be used in any comparisons between it and the same class when occurring again in the same or in any other formation; the other, extraneous organisms, the absence of which in the same class of deposit, at some other locality, would not be evidence of its geological difference, but simply of its freedom from the modifying influences which had affected the first locality.

There are many other geological facts on which much light is, at least, thrown,

if they are not fully explained, by this method of seeking types of the conditions of zoological existence at ancient epochs in the conditions of the present, and several of these are pointed out by M. Gressly, such as the abrupt terminations of peculiar petrographic deposits, the local distribution of fossils, &c., similar to the cases which may now be observed in nature, where a mud or other bank is cut off by a current, or where a local deposit is formed under the lea of projecting rocks, or the shelter of a coral reef; but it would be vain, in a limited article, to attempt to note them all, and enough has been said to guide the observer to a right mode of geological inquiry in tracing out any particular formation in its lateral extension. When the inquiry is made in a vertical direction, or by the aid of natural and artificial sections, the observer will find the same classes of deposit recurring at different intervals, and he will discover a similar analogy in the assemblage of organisms connected with them; but on close examination he will find that this is an analogy, such as similar conditions of existence must produce,—not an identity, which could alone spring from identity in the organisms of the two periods. He is thus made aware of the great geological fact which may be embodied in another rule or principle.

4. Similar variations in the conditions of organic existence must produce similar modifications in the assemblage of organic beings existing at the same epoch in the various places subjected to such variations; such modifications, however, taking place in the assemblage, and not, except in a very slight degree, in the individuals themselves. Want of identity, therefore, in the organisms of the same petrographic class of deposit, as seen to recur in a section of any part of the earth's crust, cannot be explained by a variation of the conditions of existence, the petrographic and geognostic *identity*, combined with the zoological *analogy*, shewing that the conditions were the same, but must be ascribed to a difference in the aggregate fauna and flora of the epoch; or, in other words, it proves that the organisms of the strata, compared together, were connected with two distinct acts of creation, or formed parts of two distinct organic systems or worlds.

These principles, combined with that of organic centres, have been still more fully and beautifully illustrated by Professor E. Forbes, and will be again noticed in the final chapter on the Distribution of Fossils.

Let the mode of petrifaction be now examined, and the same result as to the identity of past and existing agencies will receive further confirmation.

The relics of ancient worlds discovered in the mineral strata of the earth may, from their forms, be classed either in the vegetable or animal kingdoms. The first observers of these remarkable bodies did not overlook their resemblance to still existing organisms; but, either unable to account for their composition or situation, considered them as 'lusi' proceeding from the exercise of a plastic power in nature, or, admitting them to be the relics of real organized bodies, but not perceiving the specific distinction between them and still existing creatures, ascribed their position in the earth to one great phenomenon—the Deluge. The labours of modern philosophers have fashioned geology into a new science, by discovering in these bodies the evidence, not of one but of many phenomena, including the successive appearance and disappearance of organic bodies, under new forms and combinations suited to the varying conditions of the earth's surface. Of the number of plants which have thus lived at ancient epochs and passed away, some idea may be formed from the fact that the collection of Goëppert, author of 'Les Genres des Plantes Fossiles,' &c., contains 3254 specimens of vegetable petrifactions; namely, 236 from transition strata (Cambrian and Silurian), 1548 from the carboniferous, 34 from the "grès bigarré" and "calcaire conchylien," and 61 from the "keuper," (or $34+61=95$ from the trias or new red

sandstone), 61 from the lias and oolite, 242 from the green sand, chalk, and gypsum, 742 from lignites, 259 of unknown localities, and 50 of recent forms. These bodies (M. Goëppert states) occur in three conditions.

1. Stems, leaves, flowers, fruits, interposed between layers of stony or earthy matter, being flexible, and either slightly browned, or in various states (up to the most perfect) of carbonization.

2. Impressions of the bark of plants, the interior of which is either empty or filled with stony matter.

3. More complete petrifactions, in which the whole of the interior mass, as also the individual organs, cells, and vessels of the plant, are *filled* with stony matter, not *changed* into stone, as is commonly said.

The first of these conditions M. Goëppert illustrates by two experiments, in which he imitates the distribution of fossil plants in the shales and grits of various geological epochs. First, by the dry method. Living plants, particularly ferns, were placed between layers of soft clay, which were then dried in the shade, and afterwards subjected to heat varying in intensity up to a red heat. According to the degree of heat, the plants were found either slightly browned or perfectly carbonized; and when either powdered coal or asphalte had been mixed with the clay, they exhibited a shining black tint, and adhered to the layer of clay. When the heat had been pushed to redness, and the plants were entirely consumed, impressions of both faces were found, just as in the grits of Silesia. Secondly, by the moist method. The plants placed between layers of clay were plunged 6 feet deep in a ditch, and left there for a whole year; and the result was that they were more or less browned, as is the case also with plants naturally immersed in the mire at the bottom of ponds, and so strongly resembled the impressions of fossil plants that they might have been mistaken for them.

The second condition has not been fully illustrated by direct experiment, as it requires a combination of circumstances not easily imitated on the small scale.

In this the bark of the plants sometimes remains in a state resembling coal, and the impression of all its external peculiarities will be found in the surrounding matrix, and that of the internal surface on the stony cast formed within it. In cases like this, the cast and the mould might be taken for different bodies, as has sometimes been done. Sometimes the bark is only present as a coaly powder between the impression of the mould and the cast; and as the decomposition of the thin bark of such plants has preceded the formation of the cast, it will be found to have received the impression of the mould, and to represent therefore the original external surface of the plant, not that of the interior, as in the preceding case. When the process of decomposition has taken place under pressure, the stems are found more or less flattened, according as the pressure has succeeded or preceded the petrifaction; and in some calamites the opposite surfaces are pressed close together, the whole internal substance having been removed before the consolidation of the surrounding mass had secured it from the effect of pressure.

In the third condition of vegetable petrifactions, the petrifying matter has infiltrated into and been solidified in the interstices of the cells and vessels, the walls of which have been more or less preserved. The mineral petrifying substances were dissolved in water, and were either silica (the most general mineralizer), carbonate or sulphate of lime (not so common), peroxide of iron, smooth clay, or a mixture of several of these ingredients. This process is still going forward, as may be judged from the following examples cited by M. Goëppert. Specimens of oak received from M. Cotta and from Mr. Laspe: they were taken from a brook near Gera, having, in a space of time unknown, been fossilized by carbonate of lime, the presence of which was detected

by an attempt to saw them: the specimens are so hard as to take a fine polish, their vessels and cells being entirely filled with carbonate of lime, excepting some of the medullary rays. A specimen from M. Cotta, of beech, from a Roman aqueduct in the principality of Buckebourg: in this specimen the petrifaction is confined to cylindrical spaces which traverse the ligneous structure longitudinally, and were probably vacant spaces occasioned by decomposition, and filled up by the stony matter. The wood surrounding the petrified portions is perfectly sound; and under the microscope the exact identity of the structure of the woody and stony portions can be clearly discerned. On subjecting the specimens to the action of an acid, the earthy matter was removed, and the ligneous texture in the oak was still found to contain tannin, so that perfect decomposition was not a necessary precursor of petrifaction; an opinion which the older lithologists also advocated, even believing that there might be living portions of the plant immersed in the petrified mass. Peroxide of iron, which is constantly forming, is well suited to the petrifying process. The stave of a cask which had probably been immersed in the well of the castle of Gotha for one hundred and fifty years, is in part, especially at the junction of the hoops, petrified by this substance, and so hard as to take a polish by friction. The iron having been removed by hydro-chloric (muriatic) acid, the wood continued in a solid and coherent state. M. Goëppert was unable to discover any recent petrifaction by silica, although such had been reputed to exist. Examining the fossil woods of the ancient world, he found, by treating calcified specimens of various localities and ages, including that from Craigleith, in Scotland, that the same results were observable, the woody fibre being still exposed by the action of very dilute hydro-chloric acid. In some specimens, a bituminous oil, resembling in smell a mixed odour of creosote and petroleum, was obtained,—an additional proof of the formation of bitumen under aqueous pressure.

Wood fossilized by gypsum is very rare: a specimen from Katscha, in Silesia, weighing 4 quintals, is in the museum of the University of Breslau. The ligneous fibre is only in part fossilized, being otherwise flexible and browned. In silicious vegetable fossils, M. Goëppert removed the silica by hydro-fluoric acid, and found in many the woody fibre so well preserved that it might be used in determining the genus of the plant. In woods which, after being treated with hydro-fluoric acid, exhibit no trace of organic matter, there is no doubt that it has been removed after fossilization, either by long aqueous action or by heat. This was verified as regards heat by submitting slices of the petrified coniferæ of Silesia, which still retain a portion of fibre, to the action of a furnace, when the fibre was destroyed, and the specimens, before variously coloured, became uniformly white and opaque, the characteristic structure of the coniferæ being very distinct. It is, however, remarkable that the ligneous fibre has been preserved in many fossil woods, which, as being found in igneous rocks, such as porphyry, basaltic tufa, and even basalt, had been subjected to heat, so that it would appear that water was the principal agent in its removal. M. Goëppert examined many specimens of the fossil wood of Buchau, in the county of Glatz, which had been rolled about in a brook running from the mountain, and he ascertained that the more they were rounded and had been subjected to the action of the air and water, the less organic matter was discoverable in them, the diminution taking place from the centre outwards. If then, in this instance, the disorganization was effected in so short a time, is it not surprising that any traces of organic matter should be found in specimens which have been exposed to the air for more than 1000 years? Two specimens of fossil wood from the Desert of Egypt, which, from their appearance, had evidently at some remote epoch been rolled by water, preserve still a large quantity of organic matter. The agatized woods of Hungary occur in

the horizontal beds of a conglomerate of pumice which forms the basis of the trachytic group. These agates are externally beautifully transparent from the absence of organic matter, (which, however, exists in the narrow cells of the annular rings,) and from the water which is contained in the outer portion. Exposed to the flame of the blow-pipe, they lose their transparency, become white and opaque, and, from the dilatation of the water, split along the direction of the ligneous fibre, so that it is possible to separate the ligneous cells from each other. In the Tokay fossil wood, the colour, as well as the organic matter, is still preserved. In the Antigua agatized palms, the delicate spiral vessels can still be recognized. In general, the more organic matter left, the more coloured the specimen; but at times it takes its tint from the mineral matter itself. If the organic fibre of fossil plants exposed by the removal of the stony matter by an acid, be subjected to great heat, it is burnt away, and leaves, as in recent plants, a silicious skeleton,—another curious analogy between the animal and vegetable kingdoms: and when we reflect on all these curious facts, can we refrain from a sensation of admiration at the thought that not merely the forms of bodies, but actually the organic matter of ancient creation, has been preserved for our contemplation and study?

Reviewing also the various circumstances and conditions of fossil vegetables, extending from the most remote up to the existing period, M. Goëppert concludes that the same forces which are now in action were sufficient in the past epochs for producing the effects observed, and that the water of the ancient world *did not* possess a higher solvent power than it now does. Water will dissolve about $\frac{1}{1000}$th part of silica, and although it has not hitherto been possible to find (at least satisfactorily) a recent silicious fossil, the concretions on the bamboo, called tabasheer, and the large quantity of silica deposited in some other living vegetables, particularly in the equisetacea, are sufficient proofs of the ease with which it would enter, as a fossilizing body, into the vegetable structure.

The connection of this inquiry with the formation of coal and lignite is evident. M. Wiegmann made special experiments on the formation both of turf and of lignite in the moist way, and many examples might be cited of corresponding changes within comparatively small intervals of time. In the mines of Charlottenbrunn, fragments of ancient carpentry had been changed into lignite. Specimens of such wood-work were sent to M. Goëppert by M. Schroëtter, from the iron mines of Zurrach in Stiria, where, in the space of less than sixty years, they had been changed into resinous lignite; and others by Le Chevalier Kalina, from the sepulchres of the aborigines of Bohemia. And as a proof that even piciform coal has been formed by immersion in water under pressure, M. Goëppert cites the fact that beds of such coal actually alternate with still flexible lignite in the lignite mines of Zittau, in Upper Lusatia. M. Liebig states that in disintegration the hydrogen alone escapes; but that in putrefaction, oxygen also is disengaged. If, then, this latter change takes place under a high pressure, and at an elevated temperature, considerable quantities of carbonic acid will be disengaged, and much carbon be deposited in combination with a part of the hydrogen of the organic substance, and coal and some lignites have probably been the result of such a metamorphosis. M. Link has also endeavoured to shew, by comparative microscopic observations, that turf and coal are analogous in structure, and have proceeded one from the other; and the occurrence of stems of trees in coal is not opposed to this view, as they are also frequently found in successive layers in deep turf, such as that of Ireland. The formation of coal by immersion in water, under pressure, was, however, suggested long since by Dr. McCulloch. A similar inquiry has been instituted by Messrs. Mareel de Serres and L. Figuier, into the general principles of petrifaction,

and, specially, as an illustration of them, into the petrifaction of shells in the Mediterranean. These authors differ from M. Goëppert by supposing that the waters of the ancient ocean possessed a higher solvent power than they do at present; but this difference does not in any respect affect the results obtained, and in reality it is rather an apparent than a real difference, as the presence of much of the alkaline matter so evidently deposited at various epochs, in combination with silicic and other acids, must have enabled the water to act more powerfully as a solvent than it can now do. In fact, in this as in every other active force, the tendency is to a resulting equilibrium. *If* it has *now been attained*, the same processes will continue, but without producing any difference in the great whole of the animal, vegetable, and mineral kingdoms: if it has not been attained, such a difference, however gradually, must be produced. The long continuance of the present assemblage of created beings, without any apparent variation in the effective condition of the atmosphere, is a strong reason for believing that an equilibrium has been attained; and it may be assumed, that until such had been the case, the variations must have been sufficiently rapid to induce a much more frequent change in the aggregate of organic existences than could now be expected to take place in a world which, so far as evidence can be obtained, has only lost, during 6000 years, about twelve vertebrate animals, principally from the action of man, although the distribution of such animals has been materially modified by the local extinction of some and the lateral extension of other species.

Messrs. Serres and Figuier remark, that in order to induce the petrifaction of organic bodies, in which process the animal matter is replaced by mineral matter which preserves their most delicate forms and markings, they must be plunged in a considerable body of water, containing in solution a sufficient quantity of silicious and calcareous salts. The first part of this condition was specially fulfilled in the ancient world, when the waters occupied a much larger space than they now do, as shewn by the general nature of geological deposits; and as regards the second, there can be no doubt that the dissolved salts were in sufficient abundance. In palæozoic petrifaction, carbonate of lime was the principal agent, and the fossilization was complete in proportion to the abundance of that salt present. In gypseous, argillaceous, and even sandy deposits, the petrifaction is imperfect and the shells of mollusca often only in part preserved, whereas in calcareous deposits it is complete. In respect to the power of water to dissolve this salt, it is only necessary to observe, that though carbonate of lime is insoluble in perfectly pure water, it is soluble when an excess of carbonic acid is present, as is always the case in nature; and that in consequence *bicarbonate* of lime exists in sea water, in an appreciable quantity.*

Silica is the next most important petrifying substance, and even exceeds carbonate of lime in the extreme delicacy and fidelity of the restoration it produces. Those portions of the organic body which were capable of preserving their form for a sufficiently long time, are almost always petrified by carbonate of lime, but those of less consistency are in a silicious state. This is specially the case in the more purely animal portion of the organic structure; the ligaments of gryphæa being often silicified, whilst the shells are calcareous; the shells of ananchites and other

* This affords one of the many examples which occur in nature, of a balance between the formative and destroying causes constantly in action. Innumerable springs charged with carbonic acid dissolve the carbonate of lime of ancient formations, and carry it to the ocean, whilst the mollusca, &c., again withdraw it, and liberate the carbonic acid to return to the atmosphere. The shells of the mollusca again pass into new mineral deposits, either whole or triturated into powder: and the same may be said of the corals and other zoophytes.

echinida of the green-sand being generally calcareous, whilst their interior is either partially or wholly filled with a silicious cast; the alcyonia and sponges being usually silicified, and often in that state (as in the chalk) disseminated in the midst of calcareous rocks. These and other observations have established a strong ground for assuming, if they have not positively demonstrated, that there exists an elective affinity between silica and animal matter; and it is highly necessary, in the examination, to keep this fact before the mind, as the parts of the animal structure preserved may be very different in the two states of calcareous and silicious fossilization.

In regard to the solution of silica, it has already been stated that the water of almost all mineral and thermal springs contains a portion of silica, that it occurs in most rivers or streams, that it abounds in the stems and membranes of many vegetables, that heat and pressure combined favor its solution,—as is shewn by the great quantity deposited at the foot of the boiling Geysers of Iceland,—that the presence of an alkali greatly favors its solution, and that such must frequently be afforded in the decomposition of rocks; and further, that in the gelatinous or nascent state, in which it always occurs on the decomposition of a mineral, it is readily soluble. As, therefore, silica must have been in solution for the formation of rock crystal, so it may have been in a gelatinous state when forming calcedony, opals, and even some of the flints and cherts of various geological formations. Oxide of iron, anhydrous or hydrated, and bisulphuret of iron, have also entered into the formation of fossils: in respect to the latter, the action is as in silica, principally on the animal substance; as for example, the ammonites in shale exhibit a mere film of shining iron pyrites, which has replaced the animal membrane.

The second section of Messrs. Serres and Figuier's researches relates to the highly interesting question of the existence of *recent* petrifactions in our present seas, analogous to those of ancient geological times. In the Mediterranean, shells are immersed in a sufficiently considerable mass of water which contains in solution a notable quantity of carbonate of lime: the conditions are therefore present, and the question is, does the analogous result follow?

The Officers of the French Engineers submitted to Messrs. Serres and Figuier specimens from the neighbourhood of Algiers, of masses of shells transformed into a crystalline white limestone of a peculiar lustre, like that of alabaster. In these shelly masses, small rolled pebbles are observed encrusted by a stalagmitic glaze, which appears to be similar to the cementing substance which binds the pebbles together. The shells are all of recent species of the genera pectunculus and cardium, with a few univalves, and the rock itself is considered by the Officers of Engineers to be decidedly of recent origin. As bearing upon this interesting fact, may be cited the very remarkable recent conglomerate formed on the shore of Santa Maura, and at other localities, and which in its cohesion is fully equal to many ancient rocks of the same description; and as an example of the continued tendency to such aggregations, even from other than calcareous agencies, may be cited an interesting specimen, also from Santa Maura, presented to the author of this article by Mr. Cottam, in which several pebbles have been agglutinated firmly together by the decomposition of a nail, to which they still strongly adhere.

The Desert which crosses the road from Cairo to Suez is dotted by trees which seem to have been petrified just as they stand, and within the present epoch. The trees are only covered by sands and gravel, the whole reposing on a limestone containing oysters, the texture and colour of which are so little changed that they might be supposed only just abandoned by the sea, and which must be therefore considered as a modern formation. On the territory of Kurneel, in India, a thermal

spring has formed an abundant calcareous deposit, including numerous shells of the genera melania and planorbis, which are in various stages of petrifaction, some being entirely converted into calcareous spar, and some covered by crystals of quartz.

Messrs. Serres and Figuier state also, on the authority of others, not having examined specimens, that the cardium edule, in a petrified state, forms considerable beds at the mouth of the Somme, and that at Caneale the shells of oysters have been petrified in the same manner as in the Mediterranean.

That shells should now be petrified, it is necessary that they should remain a long time immersed in water, or in the sea. Abandoned on the shore, they exfoliate and disintegrate, are gradually broken up, but are not petrified; but the phenomena are very different when they are plunged in the water. When shells are abandoned by the animals, the first change they experience is a loss of colour, as is evident also in the solid tubes of annelides (dentalium), and in the stony polypifers: the substance is then altered, and as many of the tubercles, ribs, &c., disappear, the structure of the internal laminæ becomes displayed, and as the change proceeds, the interior of the shell is sometimes filled up by agglutinated and hardened sand, and the whole structure has at length undergone a change so perfect, that had not the crystalline carbonate preserved the form of the shell, it would be impossible to determine its origin. Some striking examples of this change are adduced; and in reply to the objection sometimes urged, that such fossils may have been washed out of tertiary beds, Messrs. Serres and Figuier observe,—1stly, that shells are found in the Mediterranean in all stages of the petrifying process, from simple discoloration to the complete transformation into crystalline carbonate of lime; 2ndly, that the molecular structure of recently petrified shells is very often different from that of ancient fossil shells, the first being usually crystalline, the others usually compact. But it is here right to remark on this statement, that in many ancient fossil shells, the crystalline structure of the shells is very perceptible, distinguishing them at a glance from the surrounding compact limestone; and this resemblance between the old and new is therefore another confirmatory argument in favor of the identity of the process at all ages of the world.

Messrs. Serres and Figuier conclude by a comparative analysis of the substance of living, of recently petrified, and of fossil shells, the result of which is very remarkable. They have properly selected genera common to the three epochs of the comparison, so that the natural or original condition of the shells compared may be considered to have been the same, and the change in that condition may be taken as a correct index of the effects of petrifaction.

OYSTERS.

	1. Ostrea edulis, variety C, living in Mediterranean.	Ostrea edulis, variety C, petrified in Mediterranean.	Ostrea, near O. hippopus, Upper Marine, Pliocene.
Animal matter	3·9	1·5	0·8
Carbonate of lime	93·9	96·3	96·5
,, magnesia	0·3	0·1	1·4
Sulphate of lime	1·4	0·7	0·5
Phosphate of lime	0·5	0·0	0·0
Oxide of iron	(trace)	1·4	0·8
	100·0	100·0	100·0

SCALLOPS.

	Pecten glaber, living in Mediterranean.	Pecten glaber, petrified in Mediterranean.	Pecten, from Upper Marine, Pliocene.
Animal matter . .	3·0	0·9	0·7
Carbonate of lime . .	96·0	97·3	96·7
,, magnesia .	(trace)	0·8	0·4
Sulphate of lime . .	0·7	0·5	0·8
Phosphate of lime .	0·3	0·0	0·0
Oxide of iron . .	(trace)	0·5	1·4
	100·0	100·0	100·0

VENUS.

	Venus virginea, living in Mediterranean.	Venus virginea, petrified in Mediterranean.	Venus senilis, Upper Marine, by Brocchi.
Animal matter . .	3·0	0·6	1·0
Carbonate of lime . .	96·6	99·2	97·9
,, mag. (trace)	0·0	0·0	0·0
Sulphate of lime . .	0·3	0·2	0·6
Phosphate of lime .	0·1	0·0	0·0
Oxide of iron . .	(trace)	(trace)	0·5
	100·0	100·0	100·0

PECTUNCULI (LADIES' COCKLES).

	Pectunculus, glycimeris and flamulatus, living in Mediterranean.	Pectunculus, glycimeris and flamulatus, petrified in Mediterranean.	Pectunculus pulvinatus, Upper Marine.
Animal matter . .	2·4	0·7	0·8
Carbonate of lime . .	97·2	99·0	98·4
,, magnesia .	(trace)	(trace)	(trace)
Sulphate of lime . .	0·4	0·3	0·4
Oxide of iron . .	0·0	0·0	0·4
	100·0	100·0	100·0

COCKLES.

	Cardium tuberculatum, living in Mediterranean.	Cardium tuberculatum, petrified in Mediterranean.	Cardium, from Upper Marine.
Animal matter . .	2·0	0·8	0·5
Carbonate of lime . .	97·8	98·7	98·8
,, magnesia .	(trace)	(trace)	0·1
Sulphate of lime . .	0·2	0·5	0·3
Oxide of iron . .	(trace)	(trace)	0·3
	100·0	100·0	100·0

Results which demonstrate in the most striking manner the resemblance, as to composition, of the recent shells petrified in the bosom of the Mediterranean to those which had undergone that change in the beds of the tertiary epoch.

When, therefore, the conglomerates now forming on the shore of the Mediter-

ranean, and the evidently similar process of petrifaction which prevailed at all epochs, are added to the more purely geological facts which the strata generally furnish, may we not conclude with these authors, that the phenomena of the ancient world are still repeated in the present, and that the same laws have presided at all epochs in producing similar phenomena; unity being at all times an essential character of the works of nature.

In the consideration then of geological formations, though the results may indicate at particular periods an unusual accumulation of certain organic bodies, we may be satisfied that the same laws have regulated their existence as those which now operate upon their congeners, and we are thus led to investigate and appreciate the various circumstances which have prepared the universe for its successive inhabitants.

THE MEANING, ORDER, AND OBJECT OF GEOLOGICAL FORMATIONS.

The preceding observations will have prepared for a right conception of the meaning which should be attached to the term formation in geological science, and of the order and object of the divisions to which that designation is applied. Under the term formation, is therefore understood an assemblage of rocks or strata which were formed or deposited at some particular epoch of the earth's history, such strata, by their mineral and mechanical structure, pointing out the physical agencies then operating in modifying the earth's crust, and, by their fossil relics, indicating the character of the vegetables and animals then living.

From a description then of each successive formation, we glean, so far as the imperfection of the remaining records and the still greater incompleteness of our inquiries will permit, a knowledge of the inhabitants of the earth, and of the plants which either sheltered or supported them, during the intervals between those great catastrophes which appear to have cut short the existence of one race of organized beings, and prepared the way for the creation of another.

Such an investigation as this is surely one of immense interest in a philosophical sense, and nearly equally so in a practical sense, as there is a mutual dependence affecting all natural causes, which enables the accurate observer to deduce the one from the other, and thus to infer the possibility or even the probability of the existence of some peculiar natural product, because he has discovered others which have been shewn, in other localities, to be closely connected with it. And here it may be observed, that in the survey thus taken of the condition of the world, both as regards its organic and inorganic constituents, during the lapse of countless ages, and amidst many catastrophes, no discovery has been made of any new principle or law. In this respect, the geologist may be likened to the unroller of ancient papyri: the one patiently unfolds the mutilated record of ancient days; but though he may discover some hitherto unknown historical fact, or trace some forgotten custom or institution, he finds every where evidence of the same passions, or of the same human creature;—and so it is with the geologist: he perseveringly examines and classifies the evidence afforded by the relics of former living creatures; but though he traces many new forms and remarkable adaptations of structure to the varying functions required by the altered conditions of life, he nowhere discovers any new principle of life or organization. The same physical and organic laws therefore have guided the world's movements, and influenced its mineral, animal, and vegetable condition, from the earliest epoch which can be arrived at in the stony tablets which geology studies and explains, up to the present epoch, when sentient beings are in existence to observe and to record them.

But it may be further asked,—were there no such sentient beings in any epoch but the one which is now passing away? This question has been generally answered by

geologists in the negative, and the absence of human fossil remains in any stratum which could be fairly removed from the existing period, has been considered a sufficient proof; but it may well be doubted whether such answer and proof can be deemed satisfactory. It is but recently that the remains of quadrumana,—that order in the animal kingdom which approaches nearest to the human animal,—have been found in a fossil state; and when it is considered that the possession of the sentient and reasoning faculties by man induces those peculiar habits which even amongst the most savage tribes leads either to the destruction of the human remains by fire, or to their inhumation in particular spots where, exposed to the deteriorating influences of percolating water, they soon disintegrate and moulder away, it may be reasonably concluded that the discovery of human fossils can rarely, if ever, be looked for; whilst the occurrence of only a single well-authenticated specimen of a human skeleton imbedded in a rocky stratum, formed during the existing epoch, is further confirmatory of the improbability, under ordinary conditions, of finding them. Nor should it be forgotten in the consideration of this question, that Professor Owen has now shewn that several still existing species of mammalia were also in existence during the tertiary epoch, so that the boundary between the present and the past epochs is not so rigidly defined as it was once supposed to be.

Reasons strong, though not equally so as the habits consequent on the reasoning faculty are here wanting, may be alleged for supposing that we have not yet discovered the first epoch of the appearance of land animals on our globe; but, as both these subjects are, however interesting, speculative, it is enough to have pointed to them as amongst those delightful springs of mental wonders which are ever flowing in to cheer and refresh the geological student in his most laborious inquiries.

In the early period of geological science, when at length some order or sequence in formation had been recognized, the terms primary and secondary were adopted,—the first being applied to those rocks, as granite, gneiss, mica slate, &c., which were then considered to be portions of the original crust of the earth,—and the secondary to those of mechanical origin; this distinction being necessarily accompanied by a further limitation from fossils, when, at a subsequent period, they had been recognized as the relics of real organic beings, and as such admitted to the secondary strata.

Ere long it appeared that some rocks, partaking of the character of those considered primary, contained organic remains, and a new term, "transition," was adopted, to express this relation or passage; but of course it involved an error of conception, as there could not really be such a passage. The progress of science has, however, gone further than the mere repudiation of this error, and it has now been shewn, almost to demonstration, that the massive primary rocks, such as granite, greenstone, hornblende rock, &c., are secondary to many of the stratified and fossiliferous rocks; and that the stratified primary rocks, such as gneiss, mica slate, and clay slate, are probably, in different countries, of very different ages, being the strata immediately below the lowest unchanged sedimentary rocks of the district which have undergone that peculiar change, in consequence of which they are called metamorphic.

It is thus that in a country occupied by the formation called Silurian, including with it the Cambrian, the metamorphic rocks must either be classed in the lower part of that system, or as strata below the lowest known fossiliferous deposits; whereas in a country occupied by the great cretaceous or chalk formation, the metamorphic rocks may be of any date more remote than that of the chalk, and possibly therefore more recent than many other fossiliferous deposits.

These changes of opinion, the result of investigation, make it necessary to qualify

the use of the terms primary and secondary, and to abandon the term transition; and in consequence, Mr. Lyell has proposed to apply the terms primary and secondary, as well as that of tertiary, as a qualifying epithet both to the massive crystalline and metamorphic rocks, and to the ordinary sedimentary and fossiliferous deposits; so that there may be primary granite, primary lava, primary gneiss, primary mica schist, and primary fossiliferous strata; and in like manner, secondary and tertiary rocks with the same designations. But it may well be said, that were it not for the difficulty of superseding terms so long in use, their total abandonment would be the most reasonable course.

In applying the term primary to fossiliferous strata, it will replace the old term transition, and therefore embrace all those strata containing organic remains which were formerly described as transition, intermediaire, grauwacken, &c. The secondary will, as heretofore, embrace a long series of formations extending upwards to the chalk inclusive; the tertiary, another series, which comes up to the base of the present system; whilst the post-tertiary may be considered as the commencement of another formation, to be completed when the catastrophe which is to close the period of this epoch of the world's changes shall have worked the destruction of the present organic creation. To be a natural arrangement, there ought to be an equality in the amount of change between these great groups, which as yet has not been established; as the change from the secondary to the tertiary appears, even after the more recent inquiries and modifications, more abrupt than that from the primary fossiliferous to the secondary. This is in part due to the uncertain position and character of the old red sandstone, placed at the base of the secondary strata by our older authors, and it is indeed difficult to decide on such strata merely from their mineral character, as in this case was formerly attempted to be done from the red sandstones and conglomerates; but if, as before observed, the broken character of many of the fossils be considered, and taken in connection with the rolled nature of the sands and pebbles as proof of drift, it is very probable that the old red or the Devonian, of which it is a part, will subdivide into two deposits, the one belonging to the Silurian or primary division, the other to the secondary.

After these few cautionary remarks as to the real value of the great divisions admitted in geology, the subdivisions may be studied with advantage, being first exhibited in a tabular form and descending order. In carrying into practice the knowledge thus obtained, the geological inquirer will first endeavour to ascertain the relative position and order of sequence of the beds he is examining, and for this purpose he will determine the strike and dip of the strata. Many very simple methods of roughly obtaining these data will occur to every Engineer, but as it is often very difficult to judge by the eye of the true inclination, as to direction, of planes, it is desirable to have a clynometer for the purpose, one of which is represented, Plate VII. fig. 36, and which may be modified or imitated by any tolerable mechanic. The true strike of the strata is often concealed by the modifying influence of elevating forces on the valley in which they are exhibited, and, unless tested, may be sometimes erroneously assumed to be co-incident with the direction of that valley. In respect to the dip, a *gradual change* in its amount from bed to bed would not be a proof of unconformability: an abrupt change affords such a proof. The sequence being determined, fossil evidence should be then sought for, in order to establish the zoological relations of the strata, and to fix thereby their geological positions.

TABULAR VIEW OF GEOLOGICAL FORMATIONS.

Class.	Order.	Groups. Marine.	Groups. Fresh-water.	Remarkable Localities.	French Synonymes.	German Synonymes.	Massive Volcanic and Metamorphic Rocks.
Quaternary, or Post-Pliocene of Lyell. These deposits must necessarily be most extensive under existing seas and lakes.	Recent.	Sand and gravel and mud. Sand consolidated. Gravel do. Calcareous grits, enclosing corals, shells, pottery, and human skeletons. Coral limestone, consisting of corals, shells, &c.	Peat, with fresh-water shells, bones of land animals, human remains, and works of art. Travertin, or calcareous deposits from mineral springs.	Delta of Rhone in Mediterranean. Shore of Santa Maura, and other parts of Ionian Sea. Shore of Guadaloupe. Newer part of coral reefs in Pacific. Kinnordy, Forfarshire. Solway Moss. Irish bogs; a rude hut found in Galway, under more than 20 feet of turf. Italy. County of Mayo, Ireland, encrusting mosses, &c.; counties of Derry and Tyrone.	Période Jovienne, or actuelle, or postdiluvial. Including Terrains alluvials, and Terrains lysiens or calcareous and silicious deposits from solution.	Alluvial gebilde. Including Turf, beds of infusoria, and bog iron ore.	Volcanic eruptions continue.
	Post-Pliocene or Glacial.	('Erratics.') Clay, sand, and volcanic tuff, with recent shells. Limestone casts of recent shells. Boulders, in sand, gravel, and clay.	Sand, clay, and lignites, with shells and fish scales. Shell marl, with fresh-water plants, and masses of solid limestone. Silt, with land and fresh-water shells.	Ischia, and other portions of volcanic district. Scandinavia. Mud cliffs of Norfolk. Beaufort, Canada. Beautiful examples of clay, of deep sands, and of gravel, supporting erratics in Ireland. Mundesley. Bakie, Forfarshire. Lacustrine shell marl, frequent in Ireland, and contains the antlers of Megaceros Hibernicus, or Irish elk, the range of which has been recently much extended. Valley of Rhine.	Here commences Brongniart's Période Saturnienne, or antediluvial. Terrains clysmiens, or detritic. Including Diluvium, boulders, and erratics. M. Brongniart classes part of the English crag here, which belongs to the next class.	Diluvial gebilde. Including Boulders and the 'los,' or sand, gravel, and loam, which contains the bones of extinct mammalia.	The action of the present volcanoes may be considered to have commenced in this period.

Tertiary. In which first appear distinctly recognized recent shells.	Newer Pliocene. Shells principally of recent species.	Loam, with marine shells. Limestone, and calcareous conglomerate.		Glasgow. Sicily.	Here begins Brongniart's terrains yzemiens, or of sediment.	Molassen generally for tertiary. Obere braunkohlen formation (freshwater).	Mr. Lyell ascribes the volcanic formations of the Val di Noto in Sicily, consisting chiefly of basalt, to this period.
			Loam, sand, and gravel, with freshwater shells, and bones of extinct quadrupeds.	Brentford, &c. Valley of Thames.	And terrains yzemiens thalassiques, or Terr. de sediment supérieurs, or terrains tertiaires.	Grobkalk formation. Untere braunkohlen formation.	
	Older Pliocene. Half, or more than half, of the shells recent.	Norwich crag: shelly sand and loam, with marine shells, and bones of land animals. Sub-Apennines: yellow sand and blue clay.		Postwick, Norwich. Sub-Apennines, Italy. The blue clay extensively developed at Corfu, rising to an altitude on Monte Sante Decca of about 800 or 900 feet.	Thalassiques proteïques, or terrains marins supérieurs.	Molassen. See ante.	Submarine volcanic tuffs of Tuscany and the Campagna of Rome associated with pliocene strata of the Sub-Apennine Hills. Extinct volcanoes of Catalonia. (Lyell.)
			Sand, with freshwater shells.	Postwick, Norwich.	Terrains epilymniques, or lacustres, or d'eau douce supérieurs. See next group.		
	Miocene. About one-quarter of the shells recent.	Red crag: red ferruginous quartzose sand, with rolled shells. Coralline crag: white calcareous sand, passing into a soft stone, with comminuted coral and shells. Faluns of Loire: similar aggregation, and marl. Bordeaux beds: argillaceous and marly deposits.		Suffolk. Orford, Suffolk. Valley of Loire, near Nantes; Angers, Tours, and Blois. Bordeaux and Dax.	See preceding group.	Mr. Lyell places the braunkohlen in this group, but Cotta divides it into two associations; the one, as the upper, with the silicious limestone and millstone of the Paris basin; the other, as the lower, with the London clay. See next group.	Extinct volcanoes of the Eifel and Lower Rhine. (Lyell.) Extinct volcanoes of Hungary. Auvergne volcanoes continue in action in this period. (Lyell.)

Tabular View—*continued.*

Class.	Order.	Groups.		Remarkable Localities.	French Synonymes.	German Synonymes.
		Marine.	Fresh-water.			
Tertiary—continued.	Miocene—continued.	Yellow sandstone, with marine shells, beds of clay, and lignite.		Corfu. An estuary formation, as seen in the citadel.		
			Blue clay and yellow sand, with mammalian bones and fresh-water shells.	Upper Val d'Arno.	Terrains epilymniques. Or Terrains lacustres, or d'eau douce supérieurs.	
			Argillaceous and marly beds, with land and fresh-water shells.	South of Bordeaux, at Saucats.		
		Yellow sandstone.		Corfu. This sandstone, with beds of gypsum, is extensively developed.		
	Eocene. Shells generally extinct.	Calcaire grossier, or coarse limestone.		Paris basin—geologically above London clay. (Prestwich.)	Thalassiques tritoniens.	Lower braunkohlen. Grobkalk formation.
		London clay.		London and Hampshire basins, including Isle of Wight. North of Germany.		
		Clay and sand.		Paris basin.		
			Calcaire siliceux, or Silicious limestone. Silicious millstone. Green, white, and gypseous marls and gypsum.	Corfu. The remarkable vesicular limestone, weathering ferruginous, and containing minute pebbles of white limestone, probably is of this epoch. Paris basin. Isle of Wight.	Thalassiques palæotheriens, or Terrains lacustres inférieurs.	Sufswasser kalkstein, with which is associated the upper braunkohlen.
		Conglomerate of white limestone, pebbles and flints.		Corfu.		
Secondary.	Cretaceous.	1. Maestricht beds: softyellowish white limestone, resembling chalk with silicious masses.		St. Peter's Mount, Maestricht. Cassel, near Mentz.	Here begin Terrains yzemiens pelagiques.	Kreide Gruppe. 1, 2, 3. Being kreide formation.
		Aggregate of corals, baculite limestone. 2. Chalk with flints. 3. Chalk without flints and chalk marl.		Faroe, Denmark. Valognes, Normandy. It is probable that the upper portion of the white limestone of the Ionian Islands, as at Paxo, containing nummulites, belongs to this epoch.	Pelagiques cretacés. 1, 2. Craie blanche. 3. Craie tufau.	
		4. Upper green-sand: marly stone, and sand with green particles. Layers of calcareous grit. 5. Gault: blue clay, with numerous fossils, passing into calcareous marl in the lower parts.		North and South Downs, and parts of Kent, Surrey, and Sussex; Isle of Wight; Yorkshire; North of Ireland. Meudon, Rouen, Beauvais, France. Some portion of the white limestone of the Mediterranean belongs to this epoch.	4. 5. Glauconie crayeuse.	4, 5, 6. Being quadersandstein formation. And to these is added our Wealden, as 'wald formation.'
		6. Lower green-sand: grey, yellowish and greenish sands, ferruginous sands and sandstones, clays, cherts, and silicious limestones.		Le Blanc (Indre); Rethel (Ardennes), Isle d'Aix.	6. Pelagiques arénacés. Including Glauconie sableuse. Sable ferrugineux marin. Lignite of Isle d'Aix.	
	Wealden.		1. Weald clay: clay (non-calcareous), sometimes including thin beds of sand and shelly limestone.	Central parts of Kent, Surrey, and Sussex. Isle of Purbeck.	Pelagiques veldiens. Including Argile veldienne. Sable ferrugineux lacustre. Calcaire lumachelle Purbéckien.	Wald formation, associated by Cotta with the cretaceous order, as the lower group.
			2. Hastings sands: grey, yellow, and reddish brown sands, sandstones, clays, calcareous grits passing into limestone. 3. Purbeck beds: various kinds of limestones and marls.	Bas-Boulonois, Beauvais.		
	Oolitic, or Jura Limestone.	1. Portland beds: coarse shelly limestone, fine-grained white limestone, compact limestone more or less oolitic, beds of chert.		Isle of Portland. Tisbury, Aylesbury. Part of the white limestone of the Mediterranean belongs to this group.	Pelagiques epiolithiques. Calcaire Portlandais, including the Grès Carpathique, or Carpathian sandstone.	

Tabular View—*continued.*

...ps.				
Fresh-water.	Remarkable Localities.	French Synonymes.	German Synonymes.	Remarks on Volcanic and Metamorphic Rocks.
	Near Kimmeridge. Sunningwell, near Oxford. Cap la Heve au Hâvre. Honfleur.	2. Marne argileuse Havrienne.	Jura formation, being, according to Cotta, the upper member of the Jura gruppe.	Mr. Lyell considers the serpentinous traps of the Morea to belong partly to this epoch, and thinks it possible that the volcanic rocks of the Hebrides may have originated contemporaneously with the lias and oolite, which they traverse and overlie. It is also highly probable that some of the basalts of Ireland were even as ancient as this epoch. The melaphyr and mandelstein (amygdaloid) are by Cotta carried into it.
	Headington, near Oxford; Farringdon; Calne; Steeple Ashton, Somersetshire; Boulonois, Mortagne.	3. Calcaire corallique, with Sable ocreux.		
	Abundantly near Oxford. New Malton, Yorkshire; Lincolnshire, Cambridgeshire, Huntingdonshire, Somersetshire, Dorsetshire; Dives and Mamers.	4. Marne Oxfordienne. Marne calcaire.		
	Malmesbury, Atford, Wraxall.	Pelagiques Jurassiques, supra-Jurassiques.		
	Whichwood Forest, Oxon; Frome.	5. Calcaire schistoide. Calcaire lithographique.		
	Bath, Burford, Bradford, Caen.	Medio-Jurassiques.		
	Stonesfield, near Woodstock.	6. Calcaire compacte commun, or Oolithe miliare. Marnes calcaires Jurassiques.		
	Cotteswold Hills. Dundry Hill. Mr. Mc Coy places *the coal* of Australia here, though the underlying limestone corresponds to the mountain limestone.	Calcaire compacte oolithe ferrugineuse.		
	Lyme Regis, Dorsetshire; and in Somersetshire and Yorkshire. Ireland, as a thin seam under the chalk escarpment, and probably extending upwards into the oolites; or if not, exhibiting the lias sandstone of Brongniart. Lignite is associated with this formation in the Irish locality, as in Wurtemburg, France, Germany, and Swabian Jura.	Terrains abyssiques. Abyssique du lias, composed of sandstone, of lias, marly gryphite limestone, alum shale.	Lias formation. Including Lias shale, lias limestone, lias sandstone; the lias shale being sometimes, from the abundance of posidonia, called a posidonia shale.	Mr. Lyell considers, as before observed, that some of the volcanic rocks of the Hebrides may belong to this epoch. It is highly probable that basaltic eruptions occurred in Ireland during this epoch, and that the great basaltic mass is, in fact, a series of alternating eruptive and metamorphic sedimentary strata. Granite uplifted at this epoch in the Alps.
	Keuper: neighbourhood of Vosges; Wurtemburg, Westphalia, Nuremburg.	Abyssique du keuper. 1. Marnes keupriques, associated with sandstone, marly limestone, plastic clay, gypsum, and sea salt.	1. Keuper formation. Keuper sandstein, with marls, gypsum, salt, dolomite, shale, and impure coal.	Mr. De la Beche considers the trappean rocks associated with the new red sandstone of Devonshire as contemporaneous volcanic deposits. M. Cotta introduces the melaphyr eruption and the formation of metallic veins here; also eruptions of porphyry and greenstone. There can be little doubt that the gneiss, mica schist, and other metamorphic rocks of a large portion of the Alps, were strata originally of this or the lias epoch, though altered during the epochs subsequent to the cretaceous: granite associated in these changes.
	Bone bed and underlying marls, Axmouth; bone bed also at Aust, Lancashire; and in Ireland, in a very confined locality at Lisnagrib, on the face of Ben Evenagh, county of Derry.	2. Abyssiques conchyliens.	Muschelkalk formation.	
	Not yet discovered in England or Ireland; extensively developed in France and Germany.	Calcaire conchylien, including marly limestone with quartz and galena, fetid and encrinital limestones, with gypsum and sea salt.	The well known muschelkalk, with marl, gypsum, salt, &c.	

TABULAR VIEW—*continued.*

Class.	Order.	Group. Marine.	Group. Fresh-water.	Remarkable Localities.	French Synonymes.	German Synonymes.	Remarks on Volcanic and Metamorphic Rocks.
Primary.	Silurian.	1. Ludlow rocks: argillaceous limestone, sandy shale. 2. Wenlock limestone: coralline limestone and argillaceous shale, with nodules of earthy limestone. 3. Caradoc sandstones: micaceous sandstone and shelly limestone, quartzose grits and sandy limestones. 4. Llandeilo flags: calcareous flags, sandstone, and schist.		Ludlow Castle, Aymestry, and Woolhope. Wenlock Edge. Dudley. Haderly; May Hill, Gloucestershire; East flank of Wrekin, and Caer Caradoc; Ireland, Desertcreat Parish, county of Tyrone. Llandmidod. Llandeilo. Extensively developed in Russia and North America, and occurs in the Falkland Islands.	Terrains hemilysiens of Brongniart, or semi-compact transition strata. Including Hem. calcareux, or limestone division, in which the Silurian is in part confounded with the mountain limestone. H. fragmenteux, or sandstone division. H. schisteux, or slate division; H. talqueux, or talc-schist division; the former transition series merging into what Brongniart calls, as below,	Obere grauwacken formation. Grauwacke and grauwacke slate, limestone and dolomite, with quartz schist, silicious schist, alum schist, anthracite, distinguished by the fossils of the English Silurian system.	Mr. Murchison considers that eruptions of trap have occurred in this epoch. There can be no doubt that granite has also been upheaved, and metamorphic rocks formed during it. The granite of the county of Down may possibly be of this epoch, and the schists of that county older.
	Cambrian.	Stratified rocks, supposed older than Silurian by Professor Sedgwick, and being of great thickness in Wales, named Cambrian. No assemblage of organic remains distinct from Silurian yet discovered.		Wales; Cumberland, &c.	Terrains agalysiens, or terrains primordiaux, to the upper division of which he allots the killas of Cornwall.	Untere grauwacken formation. Grauwacke and grauwacke schist, with limestone, &c., as above.	Granite has been upheaved during, or prior to, this epoch, and metamorphic rocks, originally of this age, as well as others anterior to it, exist. It is probable that the mica schists of Derry were originally either Cambrian or Silurian strata.

Table of Comparative Thickness of Strata.

Class.	Order.	Group. Marine.	Group. Fresh-water.	Germany, by Cotta. Feet.	England, by Phillips and others.
	Recent. Post-Pliocene, or Glacial.	Erratics. Gravel, sand, and mud.		100	
Tertiary.	Pliocene, old and new. Miocene.	Marine.		80	1248
	Eocene.		Fresh-water.	300	99
				Total . . . 380	1347
Secondary.	Cretaceous, excluding the Wealden, which forms the next class.	All marine.		1800	1080
	Wealden.		Fresh-water.	Westphalia 600 Saxony . . . 30	900
	Oolitic, or Jura Limestone.	All marine.		400	1350
	Lias.	All marine.		200	
	New Red Sandstone.	All marine.		1500	900
	Magnesian Limestone, including red conglomerate.	All marine.		1650	300
	Carboniferous, without old Red Sandstone.	Mixed marine and	Fresh-water.	600	2100 to 3000
	Devonian, or old Red Sandstone.	Marine.		From 150 to 10,000	Variable many thousand.
				Total . 16,750	
Primary.	Silurian. Cambrian.			Cotta unites these in one formation. Total . 6000	Many thousand feet.

According therefore to Cotta, the total thickness of stratified fossiliferous deposits may be assumed as 22,750 feet, or about 4¼ miles, exclusive of the variable and uncertain deposits of the existing period: such estimates can, however, be considered only very rough approximations, as the thickness of each deposit may be expected to vary in every locality, and to undergo very material modifications both in the character and in the proportions of its several parts.

GENERAL AND PRACTICAL REMARKS.

In these remarks the descending order will not be followed, but the lowest recognized strata will be first noticed, and each successive formation, growing as it were one out of the other, will in order come under review. In this inquiry it is specially necessary to bear in mind that the old notion of granite, and of other massive crystalline rocks, as well as of the crystalline schists, that they were primitive, or a part of the original crust of the earth, has been abandoned and replaced by one which admits that granite, &c., may have appeared on the surface at every geological epoch;

and that the crystalline schists may, in like manner, have been produced in their present form by metamorphic action at various periods. To express this compound relation of the schists, first, by original deposition, to the strata underlying the rocks now resting upon them, and, secondly, by metamorphic change, to an epoch or formation probably posterior to those rocks, Mr. Lyell has proposed a compound nomenclature representing both facts; as, for example, Ante-Cambrian carboniferous metamorphic strata, triasic oolitic metamorphic strata, &c., by which it is meant to be stated that the strata were respectively deposited prior to the Cambrian, and during the triasic, but reduced to their metamorphic condition by forces acting during the carboniferous epoch in the first case, and the oolitic in the second. The same principle of nomenclature he has also proposed for Plutonic or massive crystalline rocks, and for volcanic rocks, so that there may be Ante-Cambrian Plutonic, Silurian Plutonic, carboniferous Plutonic, triasic, oolitic, cretaceous Plutonic, &c.; and, in like manner, Silurian volcanic, carboniferous volcanic, triasic, &c., up to the volcanic rocks still forming. Though it may be difficult in some, and indeed in very many cases, to determine with certainty the actual epoch of the original condition, or of the metamorphic change, of the crystalline schists, and also of the upheaving and apparent partial eruption of the Plutonic rocks, or even of the eruptions of volcanic rocks, there cannot now be a doubt that the idea conveyed by the proposed nomenclature is correct, and it has therefore been followed in the tabular view of the formations. Nor does this, let it be added, in any way interfere with the doubtful theoretical question as to the true character of granite, and similar rocks; for if the opinion of Keilhau be admitted, that they are only the more advanced results of a still more prolonged metamorphic action, the nomenclature would equally express the epoch of such change as it does that of eruption in the other hypothesis.

Below all the fossiliferous strata hitherto studied, metamorphic schists have been discovered, and it is therefore evident that rocks were worn, and sediments formed into strata, prior to the strata which now exhibit in their organic relics proofs of a living organization; but can it be said that there were no living creatures during the epoch when these lower metamorphic rocks were deposited? It cannot be so said, and the argument once deduced for the affirmative of this question from the universality of metamorphic rocks, and the absence of fossils from them, must be abandoned; as many such rocks have been shewn, almost to critical demonstration, to be coeval with or posterior to fossiliferous strata; whilst the similarity of arrangement in the metamorphic and unchanged strata, as to the alternation of silicious, argillaceous, and calcareous strata, goes far to support the opinion that the first traces of organic creation in this earth are lost in the deep darkness of geological epochs anterior to the Silurian and Cambrian, the records of which have been sealed up for ever by metamorphic action. The existence of sedimentary deposits at so early an epoch, further proves that rocks had even then been brought to the surface and exposed to destructive agencies; and that the wear consequent on such action commenced before the first creation of organic bodies, may be inferred from a general consideration of the early condition of our planet, though the exact period of commencement must remain unknown.

The figure of the earth is an oblate spheroid, being the figure which a liquid body exposed to the conjoint action of gravity and a rotatory impulse would assume: in this figure then there is primary evidence of its original fluidity. That the cause of this original fluidity was heat, is gathered from an examination of the temperature of the earth's crust at such depths as can be commanded, and the fact thereby established, that below the cooled surface the temperature is found to increase on descending, so that at great depths there is yet a vast reservoir of

central heat. From numerous observations made in mines and by Artesian wells in France, England, Prussia, Russia, and elsewhere, Leonhard states that the temperature increases by 1° Reaumur, or 2¼° Fahrenheit, in 120 feet. M. Reich considers the temperature in the mines of Saxony to increase 1° centigrade in 41·84 m. of depth, or 1⅘° Fahrenheit, in 135 feet. In a boring in the Military School at Paris, the increase was found to be 1° centigrade, or 1⅘° Fahrenheit, for about 96 feet. In Mr. Fox's experiments in Cornwall, the increase was found to be about 1° in 47′. In those of Mr. Oldham, in the copper mines of Knockmahon, county of Waterford, 1° in 82′, being a lower rate of increase than that of previous inquirers. It may be therefore assumed as a reasonable approximation, though subject to many variations from the different conducting powers of different strata, that the temperature increases 1° Fahrenheit in 60 feet of depth; and if the rate of increase were considered constant, there would, at 60,000 feet, be a temperature of 1000° or that of low red heat; but as the temperature will increase with the depth in an augmenting ratio, Leonhard assumes that this temperature would be attained at about 35,000 feet, being a depth only double the height of Cotopaxi, the most remarkable of the Peruvian volcanoes. Descending still lower, the temperature, at a very moderate depth compared with the magnitude of the earth, would be found sufficient to retain the mineral matter in a state of fusion; and it is therefore unnecessary to suppose a great depth when seeking for the source of lava still pouring out in so many parts of the earth. The similarity of lava, wherever found, and the close agreement as to composition and physical characters of the basalt of ancient epochs and of that still bursting through and intersecting the walls of modern volcanoes, are further proofs that a common origin must be ascribed to all such eruptions, and that they are due, as well as the accompanying physical phenomena of earthquakes, to forces acting on the still liquid portion of the earth. The phenomena of thermal springs are also, in part, connected with this high temperature; and the greater mean density of the earth, which is nearly double that of the substance of its crust, is most probably related to its liquid condition. The proximate cause of this internal heat can be only conjectured, but whether it be electric, or the result of chemical action, or of any other kind, the fact of its existence still remains incontrovertible; and yet, before leaving the consideration of it, it seems necessary to notice some other facts which have been thought by some irreconcileable with it.

In several mines, as, for example, the iron mines of Dannemora, in Sweden, large masses of ice are found. In the mines of Ehrenfriedersdorf, in the Erzgebirge, this is called perennial ice; and, in like manner, at the millstone quarries of Nieder Mendig, near Andernach, on the Rhine, the ice is constant, during even the hottest months of the year. Such facts as these, M. Reich, of Freiberg, has shewn to be the consequence of peculiar local circumstances, arising out of the mode of working adopted at these mines. Vast cavities are formed far removed from the external surface and air, and downward currents of air are produced, which cause a rush of the cold external air towards these reservoirs of more rarefied air. Between 1790 and 1800, the ice in these depths was from 20 to 60 feet thick. Again, in examining the temperature of the lower depths of the sea, and in large lakes, it is found to decrease and not to increase with the depth. Under the Equator, the temperature of the air and surface water being 31° centigrade, or 88° Fahrenheit, Péron found the temperature of the sea—

At 390 met., or 1256 feet = 9·4° cent., or 49° Fah.
At 700 met., or 2254 feet = 7·5° cent., or 45½° Fah.

Captain Sabine, on the 13th November, 1822, in north lat. 20½°, the temperature of the surface of the sea being 83°, found, at 7187 feet, or 1⅓ mile, the temperature

$45\frac{1}{2}°$. At 67° north lat., the temperature of the air being 48°, the temperature of the sea at 4576 feet was only 26°. In the lakes of Switzerland, varying in depth from 160 to 960 feet, Saussure found that when the temperature of the surface varied from 68° to 77°, that of the bottom varied only from $39\frac{1}{2}°$ to $44\frac{1}{2}°$; but both these classes of facts are easily explained on the well-known properties of cooling water, which, as the temperature decreases, becomes more dense up to 39°, when it begins to dilate, in consequence of the commencement of a crystalline arrangement in its particles. It is thus that the cooled water naturally arranges itself below, and, circulating from the Pole to the Equator, tends to keep up a temperature in the sea bottom at most not greater than would be the mean temperature of the earth at that locality, but in many cases considerably lower; and, in like manner, the cold water proceeding from the melting glaciers of Switzerland forms a similar stratum of low temperature at the bottom of the lakes, the low conducting power of fluids rendering the passage of heat downwards very slow.

Admitting then the original igneous fluidity of the earth, and its gradual cooling from the crust downwards, it has been demonstrated by Fourier—

1. That the cooling of the earth, and the increase of temperature in proportion to the depth below the surface, has been much greater formerly than it now is.

2. That more than 30,000 years will be required to lessen by one-half, the present rate of increase of temperature; that is, to reduce the increase to $\frac{1}{2}°$ in 60 feet.

3. That the effect of central heat is now scarcely perceptible on the surface, not raising the thermometer $\frac{1}{17}°$.

4. That for nearly 2000 years this effect has not diminished by $\frac{1}{20}°$, and that we therefore see in this, as in all the great phenomena of the universe, a marked character of stability.

The earth thus cooling down must have finally attained a temperature at its surface lower than that of boiling water, and have become, in consequence, invested with a thin film of that fluid; but with the formation of a solid crust would commence disturbances and cracks, giving rise to inequalities on the surface, and thus elevating some portions of it above the circumambient liquid. At the same time, wear would begin to operate, and all these causes continuing to act, the first exposed portions may have been rapidly worn away, and sedimentary deposits formed, to be again upheaved by subsequent disturbances. In this manner the processes of wear and formation may have proceeded, until an epoch had been attained when the temperature of the earth, at some portion of its exposed surface, was sufficiently low for the conditions of organic life such as they have been exhibited in our mundane system; and if the same general physical relations of the earth then existed, that portion may be supposed to have been a Polar one, the order of formations advancing from the Poles to the Equator in proportion as the decrease of temperature extended itself. But as some of the earlier sedimentary deposits which had supported organic structures have probably, as before stated, undergone metamorphic change, and as such change recurs again at successive epochs, rendering it difficult to determine the exact zoological relations of such strata, it seems, for practical purposes, desirable to consider the metamorphic and Plutonic rocks by themselves. As rocks, they have already been noticed (page 90), and it is only necessary therefore to point out their practical bearings on the subject.

It is in rocks, more or less metamorphic, that the varieties of clay slate, called roofing slate, must be sought, and this physical condition is therefore a guide to the Engineer in his search for them: in a country of merely sedimentary character, he need not look for them, as their peculiarities and value are due to metamorphic action. It has been stated that the lesser cleavage of the slate is usually transverse

to that of the dip of the beds, and the Engineer may therefore, in examining a country, often determine on the probable value of the slaty beds by the presence or absence of this character; the planes of separation by cleavage being more regular and possessing a more even surface than those of stratification. For flagging, many varieties of the crystalline schists are excellent, the surface of stratification being sufficiently even, especially in the gneisose varieties of mica slate, and even in gneiss itself. They are also often excellent as stones for rough buildings, affording a flat bedding, and a very durable composition. As these rocks are generally quarried with ease, the expense per foot cube of flags ought not to exceed 9*d.*, and if worked with proper machinery, might be reduced to a much lower rate. In these three varieties of metamorphic schists there is a remarkable correspondence in the important physical character of specific gravity, the range in each being from about 2·6 to 3·1, the latter being the specific gravity of the more dense or indurated varieties, which become frequently hornblendic or greenstone schists. As road stones, only the latter should be used, as the other varieties will speedily break up and become mud. In selecting roofing slates, they ought to split thin and even, should not readily cleave into fragments, should not absorb much water, as, if so, they will speedily become disfigured with moss, and, by retaining the moisture, ultimately induce damp within; and they should not be scaly. Though the dark grey varieties are most approved, the silver grey are usually the most durable. Some varieties of mica slate afford good roofing slates, though they are seldom so thin and even as those connected with less crystalline schists. The most important locality in the United Kingdom is Wales, but there are also very good slates in the South-west and in the South of Ireland, as in the island of Valentia, and some in the mica slate of the North of Ireland, though the latter are not equal to the true slates. Of foreign localities, that of Lehesten in the Thuringian Forest may be mentioned. From two of these quarries which belong to the Crown, about 3750 tons of slates and about 600,000 large flags are annually raised and sold.

In respect to mica slate and gneiss as building stones, it may be observed as a caution, that in situations exposed to much wet, the gneiss, or highly gneisose varieties of mica slate, should be selected, as the finer grained, or more slaty varieties, more rapidly disintegrate; but where the building or any of its parts are likely to be exposed to much heat, as in the sides of chimneys and fire-places, the true mica schist, or the fine-grained varieties, are preferable. The city of Freiberg is built of gneiss, and the pavement of its streets is of the same material.

Of the Plutonic and volcanic rocks, the most important are, granite, syenite, porphyry, greenstone, basalt. Many varieties of granite are excellent building stones, and though expensive in working to definite forms, are most valuable. Some of the most important public works of England, France, and Russia (Petersburgh), are of this material. In selecting granite, it is right to avoid those varieties in which the constituent minerals are very small and the scales of mica superabundant, and as a practical test to notice the country immediately around the quarry, as the sandy varieties rapidly disintegrate, and give rise to accumulations of micaceous sand. The Hayter or Dartmoor granite, the Aberdeen granite, the Kingston (Dublin) granite, some beds of the Mourne or county of Down granite, and the Guernsey or Channel Island granite, are well known for their excellence. In some of the quarries the bedding of the granite is more defined than in others, and wherever this is the case, or where marked cleavages or joints prevail, the working is much facilitated. Many old Egyptian works and statues were formed of granite, and it is still used for colossal works, as it takes a fine polish: for example, the great fountain shell or vase before the Museum at Berlin, and the pedestal of

the statue of Peter the Great at St. Petersburgh, are of Northern granite, being made out of erratic blocks.* Millstones are occasionally manufactured of granite. As a road stone, those varieties which have at once a fine-grained and a close firm texture, should be preferred, as the large crystals of coarser granite are liable to cleave and break up. The specific gravity of this important stone varies from 2·5 to 2·6, which is very analogous to that of the metamorphic schists, a circumstance which gives additional weight to Keilhau's opinion that it is a metamorphic and not an eruptive rock. Syenite is even a firmer stone than granite, and its specific gravity ranges from 2·5 so high as 3·0, thus approximating it to greenstone. Many beautiful varieties of this rock are found in Ireland. In Dresden the syenite is hewn into regular parallelopiped blocks for paving, a purpose for which its durability and firmness peculiarly fit it, and as a road stone generally it is excellent. Many ancient Eastern works were formed of it, and the Giant Pillar of Melibokus was fashioned out of one block.

Porphyry.—This term extends over a wide range of species, as it may be applied to any rock in which isolated crystals, usually of felspar, are embedded in a distinct paste. As a building stone, all those varieties having a soft argillaceous paste must be rejected, but there are many which afford good rough building stones, and also good road stones, easily breaking into proper forms and sizes, binding well, keeping dry, and being tolerably free from dust,—a consideration too little attended to in the selection of road stones. From the beauty of its colours, some varieties of this rock have been largely used for columns, monuments, and vases. The red, brown, black, and green antique porphyries are well known to the student of ancient art. In modern times, the most remarkable porphyry works are at Elfdal, in Sweden, and Kolyvan, in Siberia. The Elfdal works have been established about sixty years; they are in the province of Dalarne, amidst wooded mountains, and in a wild country. The blocks are worked into form and polished by well-adjusted machinery, and most beautiful works of art in columns, vases, chimney ornaments, and tables, are turned out, rivalling the rosso-antico, or ancient red porphyry. A magnificent vase of this porphyry, at the country palace of Johannsthal, is 10 feet high, and at its summit 16 feet in diameter: it rests on a base of granite. The principal dépôt of this manufacture is Stockholm. From the workshops of Kolyvan, in Siberia, equally beautiful specimens of art are produced, and in large quantities forwarded to Petersburgh. The blocks are sometimes of great size, 300 men being employed to draw a single block. Some of the porphyries of Hungary resemble the grey porphyry, the mordiglione of Roman artists. The specific gravity of porphyry varies from 2·4 to 2·6, and it may be observed that the beautiful polish it takes is a principal cause of its extreme durability; many works formed of it remaining uninjured for ages amongst the ruins surrounding them.

Greenstone.—The specific gravity of this rock ranges from 2·7 to 3·0, and though its extreme hardness, and the difficulty of cleaving it without splinters, render it less fitted for regular buildings, it may be used with advantage as a rough building stone, and for a road stone is excellent. The porfido verde-antico, or green porphyry of the ancients, noticed under porphyry, is a greenstone porphyry, the base being greenstone, with white and green isolated crystals of felspar. The Corsican globe rock is a compact greenstone with globular concretions.

Basalt.—This rock, so remarkable for the columnar structure which is so beautifully exhibited by many of its beds, as at Staffa and the Giant's Causeway, has

* The splendid Scotch granite columns in the vestibule of the Fitzwilliam Museum at Cambridge are, from the brilliancy of their polish, beautiful examples of a modern application of this rock to the arts.

a high specific gravity, varying from 2·8 to 3·1. In its more dense varieties the hardness is very great, and makes it difficult to use it for squared work; but for rough building, and especially for walls exposed to much wear, as that from the action of the sea, it is excellent. For paving stones it would also be admirable, were it not that the surface is liable to become polished and slippery; but as a road stone it cannot be excelled, making at once a firm, durable, and dry road. Though not common, some of the sphynxes and lions of the Egyptians were formed of basalt.

The trachytic or felspathic lavas, and the various other products of ancient and modern volcanoes, naturally come into this section; but, from their rarity in the districts likely to be visited by our Corps, require little practical illustration. In the county of Antrim, largely, and in the county of Down in small quantity, trachytic porphyry has been found, assuming in Antrim a columnar structure. It appears also to be a product of the volcanic districts of New Zealand. It forms a handsome and durable building stone. Of other lava products, such as tufa, the Romans used them extensively, as is observed in the ruins of Pompeii: when porous, they are very light, and may therefore be often applied with advantage where that quality, combined with strength, is of importance. Walls constructed with them will also, from their absorbent quality, be found dry.

Ophiolite or *Serpentine.*—The mineral 'serpentine,' which name is extended to a massive and comparatively impure rock, is a bisilicate of magnesia, and has been well known from the earliest times. In all parts of the world, some of its varieties have been used in the formation of images for idol worship, and in the manufacture of vases, columns, pipes, &c. The rich green and bronze tints of its finer varieties, and the high polish of which they are susceptible, render this stone highly ornamental and valuable, and in Saxony it is still extensively worked. When veining carbonate of lime, it becomes the ophicalce of Brongniart; when porphyritic, it is his ophite.

Limestone.—The mode of association of limestone with the metamorphic rocks is very interesting and remarkable, and deserves especial attention. It is found interstratified with the various forms of mica schist, in layers varying in thickness from a mere film to several feet, and yet partaking of the metamorphic change, as seen by its highly crystalline structure. When the crystals are not of too large size, it becomes a granular marble, and when veined, as in the county of Galway, with green serpentine, forms a verde-antico. Such marbles as these, including the finest statuary marble, were formerly all called primitive limestones; but it is now evident that they are of various ages; the marble here noticed, and that of Donegal, belonging to metamorphic rocks of a remote epoch, prior at least to the carboniferous system, whereas that of Carrara is comparatively recent. In metamorphic districts, such as the mica schist country of Derry, Donegal, Scotland, &c., this limestone becomes a resource for lime, but it is impossible to notice its mode of distribution and the narrow scale of its development, as compared with the mountain limestone of the carboniferous, and the chalk of the cretaceous systems, without perceiving that the argillaceous or muddy strata have in the former much predominated.

Metallic Deposits.—It is right to notice that the Plutonic and metamorphic rocks are the great dépôts of metallic ores in Europe; and though in South America the gneiss itself is less productive whilst the ores continue into the overlying strata, it is highly probable that the latter have not been free from the metamorphic influence, and that the metallic veins have there, as in the crystalline schists, been connected with electric phenomena.

Iron.—The ore from which English iron is obtained is not connected with metamorphic strata, and will be noticed in its proper place. The celebrated Swedish iron is obtained from the magnetic iron ore connected with rocks of this class. In

Taberg, in Smoland, this ore sometimes forms mountain masses. At Dannemora, and various other places in Sweden, Norway, Russia, &c., it is in beds (Plate V. fig. 29), sometimes alternating with the metamorphic strata, and it has also been found associated with Plutonic and volcanic rocks, as with basalt. The fer oligiste, specular or Elba iron ore, sometimes replaces mica in mica schist, and is associated with adularia at St. Gothard. The peroxide of iron also forms veins and beds in this class of rocks, but it is also, as well as the other ores of iron, found beyond its limits in other classes of deposits.

Manganese.—The peroxide has been found in this class of rocks, but in a practical sense this metal belongs rather to the sedimentary deposits.

Copper.—Copper pyrites, or bisulphuret of copper and iron, the most important of copper ores, occurs principally on the Continent in gneiss and mica schist; in Cornwall, and in the South of Ireland, in metamorphic schists, being varieties of clay slate; in the Hartz in similar strata (or the old grauwacke); and in Tuscany at the junction of serpentine trap (Gabbro) with the tertiary strata. This mineral occurs also in the zechstein, or magnesian limestone, occurring there in the bituminous or copper schist (kupferschiefer). In the Oural mountains, in Siberia, the double sulphuret of iron and copper is rare, but the simple sulphuret of copper replaces it, the strata being probably sedimentary: this ore occurs also in the porphyritic district of Tyrone. The other ores of copper do not here require a practical notice.

Lead.—Galena, or bisulphuret of lead, occurs in Plutonic, metamorphic, and fossiliferous sedimentary deposits.

Silver.—Bisulphuret of silver, the most important of its ores, has been found in gneiss and mica schist and in their associated limestone, in greenstone slate, clay slate, syenite, and porphyritic greenstone. It extends up to the zechstein; but it should be here observed, that in some of these cases, as in Mexico and Peru, the veins run from metamorphic to the ordinary sedimentary deposits, and have therefore been manifestly connected with the cause of metamorphic action.

Tin.—Binoxide (deutoxide) is the most important ore. In Cornwall, the great source of British tin, and the most important one of the world, the ore occurs in granite, and also in killas, a partially metamorphic schist. In other parts of the world, it is either in granite, in metamorphic schists, or in porphyry, or porphyritic schists of the secondary class,—conforming thus to the general rule as to the influence of metamorphic action.

Mercury belongs especially to the primary and secondary class, though found rarely in mica schist or the crystalline metamorphic rocks, and in Haute-Vienne dispersed in globules in granite. The rich ore of mercury, cinnabar, of Almaden in Spain, is in the grauwacke (primary) strata, and has been worked for ages.

Zinc.—Bisulphuret, usually associated with bisulphuret of lead. The carbonate belongs to various mineral deposits, extending even to the tertiary class.

Antimony.—Bisulphuret of antimony is rare, and found in veins traversing granite, gneiss, and mica schist.

Molybdena.—The bisulphuret is found generally, in small masses, in granite and mica schist, and occasionally associated, though sparingly, with ores of tin, as in Cornwall, &c., and still more rarely with copper pyrites, as in Norway.

Gold.—This precious metal has been found in Brazil disseminated in considerable quantity in quartzose and chloritic rocks, which must be considered as belonging to the metamorphic system; and it is most probably from the decomposition of these rocks that the auriferous sands, containing also platinum and diamonds, are derived. Gold has been found in other places in veins traversing metamorphic rocks; and it is without doubt from such rocks that the Wicklow gold sands have proceeded; and

generally it may be stated that the far greater proportion of gold is obtained from such sands.

Platinum.—Found associated with gold in the auriferous sands of Brazil; in Russia, in the Oural mountains; and lately a discovery of it has been announced in France.

This general occurrence of metallic ores in rocks which have undergone a metamorphic change, though at very various epochs, their occurrence in veins, and the facts observed by Mr. Fox as to the conducting of electricity by mineral veins, and the development of metals and minerals near the contact of highly metamorphic strata, so forcibly stated by Keilhau, point strongly to an electric cause for their production, or rather their presence under such circumstances.

The mode of arrangement of metals in veins may be well illustrated by that of a mineral 'idocrase,' as given by Leonhard. This mineral resembles in composition the garnets, being a silicate of alumina, lime, and iron. At Auerbach, in Hesse, the gneiss is traversed by powerful veins of granular limestone, and just along the lines of contact, between the gneiss and limestone, idocrase occurs in considerable quantity in one of the veins (Plate V. fig. 27), penetrating the limestone in such a manner that two distinct bands are formed, one on each side of the vein,—a phenomenon which can scarcely be explained on any other hypothesis than elective affinities, induced by electric action. In the tin mines of Cornwall, opened for many centuries, the rock is traversed in various directions by veins composed of quartz, tourmalin, and tin ore. The veins do not exceed 6 inches in thickness, unite in crossing, and augment in richness with the depth. The wildness of the scenes of these deposits, and the nature of the works, are exhibited in Plate V. fig. 28, which represents the mine of Carclaze, near St. Austle, which is a vast gulf, more than half a league round, the granite being much decomposed, and the felspar transformed to kaolin.

Veins.—As the term vein occurs frequently in this section, it is desirable to give a clear idea of its meaning. The word itself conveys an idea which at once distinguishes it from dykes, as it implies a waving rather than a rectilineal course; but in reality this distinction is not always preserved, as many veins are rectilinear. Veins may, however, be viewed in two lights; namely, those which are unconnected with any great extraneous mass of matter, as they originate in and are confined to the rock in which they occur, and those which seem to arise from and to be connected with some great extraneous mass. The first class may be found in all rocks, are often so fine as to be quite capillary, and frequently intersect each other so as to form a complete net-work: they are considered veins of segregation, having been probably cracks into which the crystalline matter filling them has been gradually removed by separating from the surrounding mass. They are sometimes of quartz and sometimes of carbonate of lime. The other class of veins is often connected with large masses of external rock, the matter of which is identical with that of the veins; and it has therefore been very generally assumed that such veins are veins of intrusion, although a different opinion has been promulgated by Keilhau, who considers them only as an advanced product of metamorphic action. In Plate II. fig. 6 represents a porphyritic vein traversing the clay slate of Cornwall, at St. Agnes; it is tortuous and uneven, and might be readily supposed to originate in the rending of the mass under the pressure of the force which injected the porphyritic matter into it. In Plate II. fig. 3, a portion of the granite of Greiffenstein in the Erzgebirge is represented. This granite seems from the regularity of its beds to be stratified, and weathers, like some portions of the granite of the county of Down, into columnar aggregations, which look as if they had been heaped up by man. It is supposed that there were several distinct elevations of this granite, the highest rising about 100 feet above the gneiss, fragments of which, as exhibited in the figure, are immersed in the granite, and there-

fore illustrate a similar phenomenon in veins. Where metallic veins pass through various strata, including the sedimentary, they have most probably originated in cracks consequent on the disturbing movements beyond their limits, and have been filled partly by segregation, modified as to its results by electric currents, and partly by sublimation. Some of these veins are of great magnitude, an example of which may be cited in the great ironstone vein of the red mountain near Schwarzenberg, which is between 40 and 50 feet thick, and stretching partly along the boundary between the granite and gneiss, and partly in the gneiss itself, has been followed for more than 20,000 feet.

FOSSILIFEROUS DEPOSITS.

EARLIEST KNOWN, OR CAMBRIAN.

This term has been applied by Professor Sedgwick to the stratified rocks which occur, as in Cumberland, North Wales, and other places, for the most part slaty, and without fossils, under the decidedly Silurian strata. They contain but a small proportion of lime, and their fossils are local and rare; nor as yet has sufficient evidence been obtained to constitute of them a zoological order distinct from that of the Silurian. The apparent thickness of the slaty and gritty beds is considerable, but it is highly probable that they are repeated by contortions. The prevalence of the slaty character shews that the progress of formation has not been varied by much original disturbance, and the depth of its beds indicates the probability of some portion having been a deep sea, or rather semi-pelagic deposit. The view now taken by Professor Sedgwick is, that the Cambrian can no longer be considered a system, but a distinctly marked group in the Silurian, the Cambrian group at the base of that system.

SILURIAN.

This formation, since the publication of the splendid work of Murchison, has attracted the marked attention of geologists, and is indeed one of the most remarkable, as exhibiting the relics of organic beings in great abundance, and of very peculiar forms. It has been rescued from the formerly obscure regions of the grauwacke, and reduced to light and order by the discoveries and research of Sir R. Murchison and his followers. The lower group of this order includes the Llandeilo flags, and above them the Caradoc sandstone, the former being micaceous slaty grits. The next in order ascending is the Wenlock group, consisting of a deep bed of shale, surmounted by a bed of limestone; and the third or upper, the Ludlow, comprising the lower Ludlow shale, the Aymestry limestone, and the upper Ludlow, a calcareous grit or sandstone. As in England these groups have been found in actual sequence of superposition, they must be there admitted as distinct in order of time. But it must not be supposed that in every other region the same precise sequence is exhibited, for such would be contrary to the ordinary laws of geological deposit. In Norway and Sweden there is a similarity in lithological character, and the conditions of deposit may have been nearly the same; but in many parts of North America the limestone has been developed much more extensively, and exhibits therefore a different condition of deposit.

In this formation, the first, if we combine with it in a zoological sense the Cambrian, in which we are enabled to contemplate the earth in its most attractive form as the theatre of life, there are remains of fish, strange in form, as the genera onchus, plectrodus, but high in organization; many mollusca, including peculiar forms of the brachiopoda and cephalopoda; crustacea, highly curious and characteristic, belonging to the extensive family of trilobites, which, beginning to exist at this early epoch, flourished in number, both of species and individuals, and then rapidly passed away, the family being traced no farther than the car-

boniferous order; radiata, rare; zoophyta, less abundant than in succeeding orders, but exhibiting some peculiar forms. In respect to the conditions of deposit, it may be observed, that though the extensive limestone deposits of this epoch, adjacent to the great lakes of America, were probably pelagic, the large orthoceræ having been well suited for deep seas, the general evidence afforded by the fossils of England and Ireland, particularly by the trilobites, the flat brachiopoda, as orthis, leptæna, lingula, &c., the many species of nucula, and even it may be added by the fish as they were probably fitted to grovel in the mud, is in favor of muddy and sandy deposits in moderate and sometimes shallow depths; and the beds of limestone have probably commenced here as in the similar instances of the carboniferous system, and even of the recent epoch, by an accumulation of the remains of testacea, the temporary cessation of the influx of mud, and the growth of corals suited to such habitats.

Perhaps no region can be appealed to for information on this subject with more confidence than the small but beautiful Silurian deposit of the county of Tyrone (parish of Desertcreat), since the perfect preservation of so many species, including those of all the most interesting genera of trilobites, indicates that they are there found in the place of their actual habitation. Of the trilobites, there are Norwegian, American, and English species, the genera ampyx, trinucleus, phacops, calymene, harpes, brontes, isotelus, asaphus, illænus, being all represented in the most beautiful manner, and there accompanied by a new and most remarkable genus, the remopleurides (Porlk). The multitude of these fossils, particularly of the genus trinucleus, so delicate in its form and structure, and their association with a great number of shells of the genus nucula, leave little doubt that they lived and died in a comparatively shallow deposit, and from the nature of the gritty micaceous schist containing them, probably in one formed in an estuary.

It would be impossible to bring forward all the peculiarities of the many remarkable fossils of this formation, without entering largely into their natural history; nor in the present case is it necessary to state what fossils have been considered to characterize the subdivisions or groups of the formation: it is enough in a practical point of view to be able to recognize the existence of the formation itself; and this is of much practical importance, as its appearance at once insures to the Engineer evidence that he is below the great carboniferous system on the one hand, whilst on the other he may expect to discover below him a series of metamorphic rocks, embracing the useful deposits of various descriptions of slate and other building stones. The fossils which have not hitherto been discovered in any more recent deposit, excepting in some instances the doubtful Devonian, are graptolites, which are curious zoophytes, supposed to be related to the pennatula; the chain coral, catenifera escharoides; the genera remopleurides, phacops, calymene, asaphus, ampyx, trinucleus, harpes, brontes, and several others of trilobites; of the brachiopoda, the genus pentamerus; of the cephalopoda, the genera phragmoceras and lituites; and of the gasteropoda, the ecculiomphalus of the Tyrone beds.

It may be added in a practical point of view, that many of the schistose beds of this formation afford good flags and slates.

Besides the northern localities of Europe and America, the formation has been noticed at the Falkland Islands and in Bolivia.

DEVONIAN, OR OLD RED SANDSTONE.

This order, so long known under the name old red sandstone—a term nearly as obscure as that of grauwacke—has been recently, by the researches of Professor Sedgwick and Sir R. J. Murchison, aided by the scientific labours of Sir H. De la Beche and Messrs. Phillips and Lonsdale, raised to the rank of a distinct fossiliferous

formation. Accustomed to be viewed as sandstone and conglomerate, in the light of a drift, it appeared difficult to connect with it the limestones of Devonshire; but when it was shewn that similar limestones occurred on the Continent in similar positions, and that the limestones of the Eifel were so placed, this difficulty was removed, and the formation admitted to embrace the usual assemblage of argillaceous, sandy, and calcareous strata. In Scotland, and on the borders of Wales, the formation is exhibited in its original character of a red sandstone and conglomerate with shale and marl; the conglomerate and sandstone at the top, the variegated marls and impure concretionary limestone (cornstone) in the centre, and variegated micaceous or quartzose sandstone (splitting into tiles, tilestone), below. In the lower division, in the North of Scotland, many peculiar forms of fishes have been found, whilst in the upper, comprising the belt of yellow sandstone, the genus holoptychus appears, which extends into the carboniferous order. Were this portion of the system alone studied, it would lead to its connection with the carboniferous rather than with the Silurian, and it is still so placed by Cotta; but when the Devonshire and Cornwall strata are examined, and compared with those of the Eifel, the presence of species common to the Devon and Silurian on the one hand, and to the Devon and carboniferous on the other, impress upon them a different character. Professor Phillips has, in consequence of this mixed distribution of fossils, proposed to embrace under the general term palæozoic, the Cambrian and Silurian as the lower palæozoic, the Devonian, as the middle palæozoic, and the carboniferous as the upper palæozoic. Of 275 species examined by him in the Devonian strata of Devon and Cornwall, he states that 25 have been found in the lower division in England, 51 in the upper division in England, and 57 in the Eifel and Bensberg.

That this arrangement will require some modification hereafter, there cannot be a doubt, as new discoveries progress; and it is desirable in further comparisons to keep in view the very dilapidated condition of many of the fossils examined, as leading to the belief that they were only present in the deposit by the influence of drift. The trilobites being amongst the most distinguishing bodies of the Silurian epoch, it is curious to observe that almost every specimen described by Professor Phillips is in a shattered state. Of those which can be in any manner identified, it may be observed, that the genus harpes has been shewn to exist in the Silurian (see Report on Geology of Derry and Tyrone); the genus brontes has also occurred again in that formation in Ireland; there is a true calymene, fig. 247 of Phillips; a specimen belonging to the group which embraces the genera asaphus, isotelus, illænus, fig. 252; a phacops, fig. 249*b*; probably a remopleurides, fig. 250*e*; and the above thoracic portion and pygidium, 250*a* and *b*, which ought not to be connected with the above cephalo-thorax supposed to belong to it, are portions of a calymene; whilst the specimens figured in 248 are probably carboniferous trilobites. On the whole, then, considering that these fossils, and many of the zoophytes, &c., are present merely from drift, it is not impossible that they were living in greater abundance elsewhere at the time of the deposition of the Devonian strata, and that the actual zoological relations were closer between the Silurian and the lower Devonian, than would be inferred from these fragments of fossils alone. Professor Phillips seems also to adopt this opinion, that the analogy between the lower Devonian and the Silurian is considerable, whilst a similar analogy prevails between the upper Devonian and the carboniferous. Cotta still classes the Eifel beds with the Silurian; but it cannot be doubted that if Silurian, they occupy a higher position in the series than any of our English or Irish beds, and must therefore be parallel, as shewn by our English authors, with the lower Devonian.

In referring to this use of fossil evidence it is well to bear in mind, that any fossil species of an early epoch may be continued upwards into more recent formations, and

that the appearance of a small number of such fossils cannot therefore alone be considered sufficient to determine the age of the strata containing them to be that of the older formation: it is in the general grouping and arrangement, under the same petrographic characters, that confidence can be placed. The appearance, on the contrary, in any bed, of fossils known to be abundant in, and characteristic of, a recent formation, must always be sufficient to decide against its antiquity.

Practically, many beds of this formation, especially of the yellow sandstone, are excellent building stones; whilst the decomposition of its marly beds produces a rich productive soil. The limestones are valuable both for building stone and lime. It has been shewn by Messrs. Murchison and Verneuil, that in Russia, south of Petersburgh, a large area, formerly supposed to belong to the new red sandstone, is of this geological age, though abounding in saliferous and gypseous beds. This identification has been made from an examination of the fishes or ichthyolites; and in noticing it, the remarkable fact should not be overlooked, that salt deposits have, in very similar circumstances, been formed at various geological epochs. It need not be urged how important the determination of this formation is, in estimating the probability of finding coal; for example, it had been stated that a conglomerate of the Ionian Islands belonged to the old red sandstone, and that some thin beds of lignite appearing in superjacent strata were of the carboniferous epoch, such a statement necessarily raising much false hope of finding productive beds of coal; whereas the conglomerate is tertiary, and the lignites of the same class.

CARBONIFEROUS.

This formation, the most important of all in its economic characters, is a vast assemblage of calcareous, arenaceous, and argillaceous strata. If it be considered that the great masses of limestone were formed in deep seas, whilst the coal shales were formed in estuaries, and, in some cases, in lakes, it is evident that where the limestone division prevails, the shales may be expected to diminish, and to lose their estuary character, so that coal will become less abundant. This is the case in Ireland, and accounts for the comparative scarcity of coal in that country.

The great limestone deposit which forms the basis of this system has been called the mountain limestone, and is characterized by many peculiar fossils. In the Southwest of England, in Somersetshire and South Wales, this limestone is strongly marked, and is separated from the coal measures above by a thick deposit of arenaceous strata; but in the North of England, the coal descends into the millstone grit, and even alternates with the upper beds of the mountain limestone; and in Scotland, this mixture of marine strata with those containing coal is still more marked. In Ireland, many of the masses which constitute the mountain limestone are also separated into distinct beds by shale; but as coal does not occur in the layers of shale, they may have been also deposited in a tolerably deep sea, whilst in other instances they were doubtless estuary formations. It is thus that in the Mediterranean much of the coral living at the bottom of its waters is subject to be covered over by the mud moved along by the currents.

The presence not merely of a vast variety of terrestrial plants in the coal shales and grits, but in some cases of fresh-water fossils, such as the genus cypris, induced the belief that some of these deposits have been lacustrine, but whether formed in actual lakes, or at the mouths of rivers occasionally dammed up, and formed temporarily into fresh-water lakes, cannot be determined. The fossils of this formation are very characteristic, and a few will be figured to guide the Engineer in determining the probability of having at any time discovered it. In the plants, so rich in various forms, resembling the tree ferns of the tropics, there is evidence of a climate re-

sembling that of our most Southern regions, and this is confirmed by the great abundance of sauroid fishes, and of cartilaginous fishes of the families of squalidæ and raiidæ. The crinoids are largely developed, and the corals are rich, many of them being lamelliferous, as is the case with those now forming coral reefs; and it is peculiarly necessary, in studying this formation zoologically, to keep in view the difference of habitat of corals, many being confined to reefs, whilst others live in shallow water on the coast, and are frequently enveloped in mud.

That coal is the product of ancient vegetation entombed in mud and sand, and in the course of ages altered to its present state by gradual chemical change, cannot be doubted; but whilst some maintain that the plants have grown where the coal now exists, others have considered it to have been formed of plants washed down into estuaries, and there accumulated; whilst again, a third party has advanced the idea, and endeavoured to support it by microscopic investigation, that the coal resembles rather the product of a bog or peat moss. It is highly probable that each of these opinions is correct in certain localities; but in either case, the alternations which must have taken place are very remarkable: Mr. Phillips, for example, states, that in the North of England, the total thickness of the coal-bearing strata may be estimated at 3000 feet, whereas the coal itself is separated into nearly thirty seams, the whole thickness of which does not exceed 60 feet; the thickness of the seams being very variable, from a few inches to many feet, though rarely exceeding 20 or 30 feet. At Dombrowa, in Russian Poland, there is a seam 42 feet thick, which has been traced continuously for 7000 feet in length. Taking all the minute seams into account, the total number in the Newcastle district is forty; at Dudley there are eleven, one only being worked. In the coal district of Saxony, the seams vary from three to eight. At Mons, there are 115 workable seams, few, however, exceeding 3 feet in thickness. In Colebrook Dale, there are 135 seams, the total thickness of which is 500 feet. In the Département du Lot, it is said that a shaft has been sunk for 72 feet in a single seam, which is supposed by some to be 300 feet thick, but it is probable that this is either a mere deposit in a deep hollow, or that the seam has been thrown up, and is pierced in a longitudinal rather than a transverse direction, such as would be the case in working, from above, the seam represented in Plate VI. fig. 33.

The contemplation of such masses of vegetable matter, composed of plants long since passed away from the living world, of which more than 300 have been figured and described, 200 belonging to the order of ferns, and others to giant mosses, and to cellular plants, leads to the perception of peculiar conditions of organic life. It is true that some of these conditions have been repeated, though in a fainter degree, at subsequent epochs, and given rise to limited carbonaceous deposits; but as the progress of the various changes, physical and organic, working in the earth's crust, was towards the present state of things, an approximation to the conditions now observable, and a receding from those which once so greatly promoted the growth of succulent plants, are in strict accordance with the laws of nature. As, for example, the influence of central heat diminished in its progress southward, successive portions of the earth may have become fitted, though in an inferior degree, for the support of such plants, and partial deposits therefore appear at such epochs; nor should it escape attention that when the Polar regions were first brought by the diminution of central heat to the proper temperature, they were, from the deficiency of solar heat, better fitted for such vegetation, the temperature being equable and unattended by the scorching effects of the sun's rays now felt in Southern regions. Though the seams are sometimes extended over a wide space, the general character of the deposit is that of a basin, and nowhere else is the phenomenon of faults

more strikingly exhibited, the seams being sometimes thrown up or down several hundred feet. Plate IV. fig. 20, and Plate VI. fig. 34, illustrate this form of internal movement; and Plate VI. fig. 32 is a horizontal representation of the manner in which the seams are worked. Fig. 34 represents the mode of sinking the shaft, and also exhibits a remarkable form of contortion, the seam having been bent vertically upwards. Plate V. fig. 29 is a representation of the iron mines of Dannemora, from Leonhard, which, although the deposit is not of this date, may be used to illustrate generally this class of mining. The faults here described are sometimes accompanied or caused by dykes, but in other cases they are not so, and are in character dislocations, attended with slips. The knowledge of the various forms of such faults, and of the direction in which the suddenly lost seam should be sought, constitutes one of the most difficult points in mining science.

Dr. Ure gives the following Table of the quantities of coal exported from the several ports in England, Wales, Scotland, and Ireland, in 1836 and 1837; and there can be little doubt that the exportation has vastly increased since, independently of the internal consumption in the coal districts.

	1836.	1837.	Increase.		
	Tons.	Tons.			
England and Wales	6,757,937	7,570,254	812,317	or 12·02	per cent.
Scotland . .	624,308	626,532	2,224	or 0·36	„
Ireland . .	7,027	7,515	488	or 6·94	„
Total . .	7,389,272	8,204,301	815,029	or 11·03	per cent.

In Fuller's time (1661), 200,000 chaldrons were imported annually into London, but now the consumption is nearly 3,000,000 tons, which is brought into port in about 9700 ships. The annual quantity raised is estimated by Mr. Taylor at 15,500,000 tons, and Durham and Northumberland, he considers, could meet that demand for 1700 years to come.

Mr. Porter deduces from the French Mining Reports the following data:

Coal is raised in thirty departments of France, in which 258 mines are in operation, and 21,913 workmen employed. In 1814, the quantity raised was 665,000 tons; in 1825, the quantity had doubled; in 1832, the produce was 1,600,000 tons; and in 1836, it amounted to 2,500,000.

Cotta has given (1839) a statement of the production of coal in the several coal districts of Europe, which is valuable for comparison:

	Tons.
In England	20,769,231
Belgium	5,215,385
France	2,215,385
Prussia	1,569,231
Russia	738,461
Austria with Bohemia . .	184,616
Bavaria	32,308
Saxony	28,616
Sweden and Norway . . .	28,293
Hanover	21,646
Spain	18,462
Both Hesse	15,231
Sardinia	4,662
Weimar	1,939
Portugal	415
Total	30,843,881

And Dumas gives, in 1828, the following comparative values of the coal produced:

	Francs.		£.
England	90,000,000	=	3,562,500
Low Countries, including Rhenish Provinces and Luxemburg	37,000,000	=	1,464,583
France	12,000,000	=	475,000
Russia, Silesia	3,600,000	=	135,000
Hanover and German Confederation	3,600,000	=	135,000
Total			5,772,083

Both these Tables concur in stating the product of the British coal fields as double that of all the rest of Europe; and there can be little doubt, if we examine the rate of increase in Dr. Ure's Table, that Cotta's estimate is not beyond the truth,—at least in the present time,—and that the gross value of the collieries of Great Britain and Ireland cannot be estimated as less than £8,000,000 sterling.

But this is not the only valuable product of the formation. The argillaceous carbonate of iron, or clay ironstone, which is the principal ore of iron used in the British Isles, occurs in beds in the coal shales, thus putting in contact with each other the mineral ore and the fuel for smelting it. In 1826, the quantity smelted into cast iron was between 600,000 and 700,000 tons; and as there had been a steady increment up to that time, which must have gone on during the last few years with at least an equal intensity, the present quantity cannot be estimated at less, stated in round numbers, than 1,000,000 tons of bar iron, being in value equivalent to £10,000,000 sterling. In France there are iron works in sixty out of the eighty-six departments. The number of establishments in 1836 was 894, and of workmen 15,738, the product being 303,739 tons of pig iron, and 201,691 tons of bar iron, valued at £3,580,000.

Nor are the resources of the formation yet exhausted. The mountain limestone, which is its pelagic equivalent, and is strikingly remarkable as exhibiting in its layers of silicious or chert concretions a strong analogy to the subsequent pelagic deposit of the chalk, is in England the source of much mineral wealth, and produces more than one-half of its lead. The proportion due to this formation cannot be assumed as less than 26,000 tons, equivalent to about £520,000 sterling; so that, from this formation alone, mineral wealth is annually produced in Great Britain to the amount of nearly £19,000,000 sterling. And to this should be added also the value of the lime and marbles, or other building stone, produced from the limestone, and of the excellent building stone which is obtained from many of its grits; as for example, in the neighbourhood of Glasgow, the beauty of that city being the consequence of the ready acquirement of such excellent materials. And if the mind passes from the crude or simple value of the materials themselves to the contemplation of the vast results proceeding, in further stages of production, from coal and iron as used in the machinery of its manufactories and railways, it discovers in the possession of so large and productive a portion of this formation, the source and foundation of the commercial, and, in consequence, of the political greatness of Great Britain.

Can any one then hesitate to admit, that a science which enables the Engineer to trace out such a formation in other countries, which gives him first a clue as to its probable existence in particular regions of the world, and then the data for deciding whether he has or has not found it,—must be a science of the utmost practical value, and deserving all the labour which may be necessary to acquire a sound knowledge of it? Already has Great Britain in her colonial possessions of New Holland another coal formation, and should this deposit hereafter prove a productive

one, though by Mr. M^c Coy believed of a more recent epoch, it may be the proud lot of her countrymen to have planted there the seeds of another mighty empire, destined in time to rival in all the elements of its greatness the country which has given it a social and political birth.

In America, there is an extensive coal formation including both blind and bituminous coal within the limits of the United States, likewise in Nova Scotia, at Picton, and Cape Breton. In Asia, China and Japan are supposed to possess extensive deposits. Such then is the lateral distribution of this valuable mineral formation, drawing nearer to the Southern regions than the Silurian; and, as regards its position vertically, it is very variable, many of the seams at Newcastle being worked under the sea, whilst at Chipo, which rises above the plain of Santa Fe de Bogota, it is found at 8000 feet above the sea, and at Huanoco at 12,800 feet, or at the limits of eternal snow.

MAGNESIAN LIMESTONE.

As the mountain limestone is of great practical importance, being the basis of the carboniferous system, so is this formation, including its underlying red conglomerates and sandstones and marls, of similar importance, as immediately overlying the rocks of that great system. In the South-west of England, its strata are unconformable to those of the carboniferous system; but in the North-east they are conformable, and there seem to form part of that formation. In all formations, cases of this partial conformability between the upper and lower may be expected to occur, according as the disturbing movements are more or less extensive or local; and it was therefore necessary to determine the great geological divisions from a general and not from a partial examination.

In the lower red sandstone of this order there is a strong resemblance to the upper, or distinctly new red sandstone, whilst in the fossils there is a close approximation to the carboniferous, the genera producta and spirifer of the brachiopoda occurring in each; and of fishes, the genus palæoniscus. This remarkable genus of fishes cannot, however, be said to go no higher than the magnesian limestone, as the sandstone and marly beds of Rhone Hill, in the county of Tyrone, in which the palæoniscus catopterus occurs in profusion, associated with posidonomya minuta, huddled together in a small patch or pool, appear to belong distinctly to the true new red sandstone. On the other hand, the spirifer undulatus (Sow.), supposed a characteristic species of the magnesian limestone, occurs in Ireland in beds which are overlaid by apparently well-marked carboniferous limestone. On the Continent, the name "rothes todtliegendes" has been given to the lower red conglomerate, to distinguish it from the white grits which immediately underlie the kupferschiefer or copper slate, and which sometimes also contain copper ore, which the red-*dead*-lyer does not. In England, the copper slate and the white grit do not exist, and this lower red sandstone and conglomerate immediately underlie the magnesian limestone. Cotta places it in the carboniferous system, making the white grit the base of the magnesian limestone formation. In England, the formation in the South-west is principally composed of the drift or conglomerate beds, exhibiting, however, the peculiarity of a dolomitic or magnesian limestone paste as its basis. In the North-east it is characterized by a yellow magnesian limestone, passing upwards and downwards into marl slate and marl with gypsum. On the Continent, the zechstein, which is a dense but sometimes porous grey, and generally fetid magnesian limestone, becomes complicated upwards with marls containing many extraneous substances, such as ironstone, gypsum, and rock salt. It is in the upper beds that the gypsum and rock salt prevail, being an approach to the character of the true new red. The county of Mansfeld is the richest locality of the formation, where the workable portion of the copper slate

has a thickness varying only from $1\frac{1}{2}$ ft. to 2 ft., and gives rise in numerous establishments to one of the most difficult of mining operations, called there krummhölzerarbeit, or crooked-stick work, the miners crawling and working in low cavities, only 18 or 20 inches high, lying upon their sides and being supported by pieces of bent timber or crooked sticks. In England, the formation is practically valuable from the excellent building stone which some of the magnesia beds afford, the tint being specially favorable for Gothic buildings. York and Beverley Minsters exhibit favorable examples of the stone, but there is great difference as to durability, according as the more purely magnesian limestone or the gritty beds have been used. This stone has been selected for the New Palace of Westminster as the best building stone of England.

The occurrence of dolomite, or the compound carbonates of lime and magnesia, in so many localities associated with rocks of an igneous and even eruptive character, induced Von Buch to propose a peculiar theory, viz. that the magnesia had been introduced into the mass by sublimation, being one of the igneous phenomena manifested in the eruptive rocks. He did not mean that the contact with such rocks had caused the change, but that such contact explained the other phenomena by pointing to the proximate cause of both. In like manner the porphyritic rocks, and even the amygdaloid, which are sometimes associated with the red-dead-lyers, and even cut through them, might be considered to indicate similar actions, and, in consequence, some have supposed the irregular surfaces of the magnesian limestone to be the result of such causes having induced a peculiar crystalline arrangement; but Dr. Daubeny explains these irregularities on the same principle as they are explained in the chalk and other calcareous rocks by the action of water holding carbonic acid in solution; and, on the whole, the mode of formation of this peculiar rock must be yet considered doubtful. The class of reptiles was supposed to begin in this formation, but Mr. M^c Coy gives good reasons for admitting their existence in the carboniferous.

NEW RED SANDSTONE OR TRIAS.

This formation, from the prevalence of a variegated character in its sandstones and marls, has been sometimes called "poikilitic." On the Continent, where its several members are better developed than in England, it has received the name of "trias," from the possibility of dividing it into three great and satisfactory sections. The lowest of these is the "bunter sandstein," or variegated sandstone, a red sandstone variegated by greenish stripes and spots, and containing clay galls; the sandstone being associated both above and below with variegated red and green marls, containing both laminated and fibrous gypsum, and rock salt. As the muschelkalk, or central division, is deficient in England, and gypsum and rock salt occur on the Continent in the marls, both in the upper and lower division, it is difficult to decide generally whether our salt-bearing strata belong to or should be separated from the more decided sandstones and conglomerates which underlie them. The white sandstone of the Vosges belongs to the lower division, or variegated sandstone; and wherever this freedom from the usual colour prevails, the grits become valuable building stones.

In Thuringia and Swabia the muschelkalk division is fully developed, the limestone under several forms or varieties alternating with marls and clays which sometimes contain gypsum and rock salt, and is occasionally dolomitic.

In the upper division or keuper, marls and clays prevail, though still associated with sandstones. Gypsum and rock salt still occur, and sometimes an impure coal. As fossils are extremely rare in the sandstone divisions, it was scarcely possible to allocate to their proper place in this triple system the English beds; but the fossils of a dark marly stratum which occurs at Axmouth, and on the banks of the Severn in

Gloucestershire, and is called the bone-bed, have been proved to belong either to the keuper or muschelkalk: these are, Hybodus plicatilis, Saurichthys apicalis, Gyrolepis tenuistriatus, G. Albertii,—of which it is very remarkable that Saurichthys apicalis, Gyrolepis Albertii, G. tenuistriatus, have been also found in a seam of calcareous grit connected with black shale in an equally local deposit on the face of Ben Evenagh, at Lisnagrib, county of Derry, the Acrodus minimus, another muschelkalk fossil, being there added to the list. It may therefore be reasonably inferred that though the muschelkalk is not fully developed in the British Islands, there are at least two members of the series, with a trace of the other.

As connected with this formation, the remarkable foot-prints ascribed to an animal, to which the name of chirotherium was given, should be noticed. Various conjectures as to the nature of this animal were hazarded, but Mr. Owen has recently proved that they were formed by the animal to the teeth of which he had attached the name labyrinthodon, from their peculiarly complex structure; and he has further proved that these creatures belonged to the batrachian order, or were gigantic frogs. The genus ammonite of the cephalopodous molluscs here first appears; and in the flora as well as fauna there is a striking difference from the underlying strata, the species of forty-seven genera noted by Professor Bronn being quite distinct.—*Footsteps of supposed Wading Birds observed in America.*

The great characteristic of this formation in England is, that it is the deposit of rock salt. In Cheshire, the alternating beds of red and green marl with gypsum and rock salt sometimes exceed 600 feet in thickness; and at Northwich, the two beds of salt are at least 60 feet in thickness, and extend laterally for 1½ miles. In Ireland, the gypsum prevails more than the salt; but even there, on the line between Belfast and Carrickfergus, there is reason to believe that the salt may be found. And generally this curious connection of the sulphate of lime with the chloride of sodium deserves attention, as affording a probable indication of the occurrence of salt in other formations. The average quantity of salt manufactured in Cheshire may be stated at about 250,000 tons annually. The celebrated salt-mines of Wieliczka, in Galicia, belong to the cretaceous formation.

LIAS ORDER.

This formation, in which argillaceous matter or clay preponderates, being associated with argillaceous limestone, marl, sandy marl, and sandstone, is remarkable as being what may be considered the special locality for marine reptilia; for although the genus icthyosaurus had already appeared in more ancient deposits, it seems in these to have attained its full development, and is accompanied by the equally singular genus plesiosaurus. The existence of a marine saurian amidst the Gallapagos Islands, as noticed by Mr. Darwin, is highly interesting, as exemplifying the probable mode of existence of these vast animals, and their habits, which may have also been in conformity with those of the crocodile. That curious genus of cephalopodous molluscs, the belemnite, also first appears here, and the gryphæa, a genus of the family of oysters, is abundant; and the abundance of such animals proves the marine origin of the deposit, and confirms the fact that marine saurians were, at that early period, swimming in multitudes around the muddy shores of the then existing land. The characteristic colour of the limestone, which sometimes assumes a riband-like arrangement amongst the argillaceous beds, is blue, but there is occasionally a white variety, and in some instances sandstone prevails in the lower members; as for example, in Würtemberg, where sandstones of brownish and yellowish hues are associated with marls and limestones in the lower lias, the upper being composed of dark lias shale and limestone. The lias shale of Würtemberg is so

rich in a species of the genus posidonomya, the P. Bronnii, that it is even called the posidonian shale; and it is right to notice this fact, as the similar occurrence of that genus in shales of the carboniferous period, and in marls of the new red, is highly illustrative of the general character of such deposits. Some thin beds of pitch coal occur also in the shales, which, as well as the limestones, are strongly impregnated with bitumen, proceeding, it is very probable, from decomposing animal substances, such as fishes, &c., which abounded at the epoch of their deposition. Practically, the sandstones are sometimes sufficiently firm to be used for building, though they usually become iron-shot, or stained. The limestone is occasionally hydraulic, and the soil is generally fruitful.

OOLITE OR JURA FORMATION.

The clays of the lias form the basis of the oolitic system, and in ascending into it, other argillaceous bands mark those changes in the conditions of deposit which are to be expected in every great formation, representing, as it must do, the variations of drift consequent on the changing direction of currents. These bands have, in England, led to a division of the oolites into lower oolite resting on the lias; the middle oolite resting on the Oxford clay, which separates it from the lower oolite; and the upper oolite resting on the Kimmeridge clay, which is between it and the middle oolite: but it must be evident that such clay bands, being merely the result of local causes, cannot be expected to occur in all localities at the same time, or to produce a similar division in all countries. On the Continent, the formation has been divided simply into the upper and lower Jura, the upper being characterized by a light-coloured, whitish or yellowish limestone, which forms the great mass of the Jura Mountains, and has derived from them its name,—the lower consisting of roe-stone and dolomite, the latter being penetrated by holes or cavities; and of sandstone, marl, and clay. In the Jura limestone there are partings of hornstone, strongly resembling the flints of the chalk; and its surfaces exhibit also very beautiful dendritic markings of oxide of manganese, equally resembling those of the hardened chalk of Ireland; so that the first impulse of one acquainted with the Irish chalk, in looking at this rock, is to exclaim that it is chalk. The Bavarian Jura formation is remarkable for the numerous bone caverns of its dolomites, and for the celebrated lithographic stone of Solenhofer. The wooded hills of Pappenheim are composed of a regularly stratified limestone arranged in thin and horizontal beds. The stone is extraordinarily pure and dense, yellow or grey in colour, and, from the thinness and regularity of its layers, peculiarly fitted for lithography. The hills themselves are distinguished by their broken aspect and wall-like character, which makes them look like so many fortresses; and on entering the valleys, the ringing sound of the proper lithographic stone, as it is broken up for use, is heard on all sides. The layers used for this purpose are from 1 to 4 inches thick, and when they are still thinner, or are unfit, by containing fossils, for lithography, they become useful as roofing tiles, as door and window linings, as tables, &c., to which purposes they had been extensively applied long before the invention of lithography. These peculiarities of the physical features of the country, and of the mechanical characters of the stone, deserve to be remembered in looking out for good lithographic stone in other countries. In addition to the defect consequent on the presence of large fossils, veins should be carefully avoided, as in printing they mark the drawing, however fine they may be, with white lines, and increase greatly the difficulty of bringing the surface of the stone to a uniform state. In the English oolites, the most remarkable is the Stonesfield slate, lying at the base of the great oolite, a member of the lower division: it is a slightly oolitic limestone, and though

only 6 feet thick, abounds in fossils. With impressions of ferns and other terrestrial plants, the elytra of beetles and the remains of saurian genera already noticed, occur those of the pterodactyl or flying lizard, and what is more remarkable, the jaws have been discovered of at least three species of mammiferous quadrupeds of the marsupial order,—partly allied to the opossum, and partly to the myrmecobius of Australia,—a singular analogy, at this early epoch, to a region now so widely distinct in its fauna from other parts of the world. In the lower division also occurs the Bath oolite, which affords such an excellent stone for the delicate mouldings of Gothic architecture, and is represented in France by the Caen stone, which is even better fitted for the purpose, and was in consequence imported by our early architects, the beautiful Temple Church being a favorable example. In the middle oolite is the "coral rag," so called from the continuous beds of corals of which it is composed, and which still retain the position in which they originally grew. In the upper oolite is the celebrated Portland stone, so well known for its beauty as a building stone.

Many parts of this system in various countries are distinguished by a profusion of some particular fossil which is always a characteristic of a regular deposit, as distinguished from a drift: such, for example, was the surface of the great oolite when studded over with pear-encrinites, which were afterwards buried by the irruption of the Bradford clay; the clays of the upper oolite with their oysters and gryphites (ostrea deltoidea and gryphæa virgula); the nerinæan limestone of the Jura, distinguished by a peculiar univalve genus nerinæa and the diceras limestone of the Alps, so called from the abundance of the very curious bivalve genus diceras.

Although in this formation the great body of the fossils demonstrates a marine origin, the frequent occurrence of fragments of wood, the coal beds and bituminous shale which enter into the system, the many impressions of plants and insects, the abundance of those saurians and of encrinites which may be considered as more fitted for shallow than for deep waters, and, above all, the actual discovery of land animals, all concur in proving that the deposit was formed in the vicinity of land; and it becomes therefore an interesting precursor of the next formation, in which the evidence of land is further connected with that of a then existing lake.

WEALDEN FORMATION.

This formation, remarkable from the evidence of the fresh-water origin of its deposits, is not entirely free from marine fossils, so that it has rather the character of an estuary than of an inland lake. On the Continent, it has been associated with the cretaceous system; and as the lower beds of the green-sand correspond closely with some of those of this system, and in France the fresh-water beds are sometimes separated by marine beds, supposed to belong to the green-sand, this allocation may be considered correct. In England, however, it is remarkable that the oolitic beds must have been first raised up quietly without any great disturbance, as the celebrated 'dirt-bed' of Portland, with its upright roots, rests horizontally upon them, the roots even penetrating into the subjacent oolite, and that subsequently portions of the compound deposit were thrown out of the horizontal position, as appears in the section at Lulworth Cove. If the principal basin, in which these beds have been traced, extending at each end from France into England, be really continuous, the deposit is very extensive, whether it be considered lacustrine or estuary, but of course it may have been much interrupted, and formations of a different character contemporaneously deposited within its area. Such problems are of very difficult solution, as it is almost impossible to bring back to the mind the actual condition of the earth's surface in respect to land, sea and river, at each successive epoch of its history, darkened as it must be by the effects of reiterated changes and unceasing wear.

The vast estuary which it has been necessary here to assume, became subsequently exposed to the action of the sea, and the dry land existing on its margin, or as islands within its precincts, was covered by the marine deposits of the cretaceous epoch, some of which indicate a depression of this land sufficient to have allowed of deep sea deposits. That this was the case is proved by the remarkable denudation of the Weald, in which the superincumbent strata of the chalk having been uplifted and broken by subterranean disturbance, and then carried away by the denuding wave or current, the fresh-water strata of the Wealden have been exposed; and as they are again seen on the opposite coast of France in the Bas-Boulonois, a remarkable valley or basin of the Wealden has been thus formed within the area of the greater estuary it originally occupied. A similar and somewhat parallel disturbance has also forced up the Wealden strata in the Isle of Wight. These undeniable proofs of disturbing forces assist the inquirer in understanding those which preceded them, as the facts not merely shew that the vast basin of the Wealden had been forced up and broken at various parts of its area, after the deposition within it of deep sea drift, and the accumulations of the cretaceous strata, but that this basin itself had been formed by a gradual depression of the earth's crust, after the distinct existence of dry ground covered with trees, as exhibited by the Portland dirt-bed. Such oscillations are indeed wonderful, and difficult to be reconciled in the mind with the comparative quiet which now reigns on the earth; but we become acquainted with them from geological investigations, as we do with the facts, the habits and opinions of past ages, from historic records; and we owe therefore to this science the knowledge we now possess of changes which, without it, would have been unknown to us. In England, where the formation is more extensively developed than in any other country, the base of it is the well-known Purbeck limestone, distinguished by the profusion of fresh-water shells it contains. This portion of the formation, the beds of limestone being separated by marls, is about 250 feet, which must be considered an immense depth for a fresh-water deposit. The Hastings sands with clays and calcareous grits succeed, and are about 400 feet thick, being as extraordinary as a fresh-water drift, as the Purbeck limestone is as a calcareous deposit; and the whole is covered by the Weald clay, being, with its thin beds of sand and shelly limestone, about 200 feet thick. This formation, taken together, implies the existence for a long time of vast areas of fresh-water resembling those of North America, in which at this moment, from the continued wear of their banks and the depth of their bottom, which in some cases is 16° below the level of the sea, there can be no doubt extensive deposits must be forming. Mr. Robertson has recently proved the existence of Wealden beds at Brora, in Sutherlandshire, and advanced strong reasons for associating the Yorkshire coal also with this formation.

Though not marked out in the same striking manner as in England, this formation of fresh-water deposits can be traced in other countries; and it is evident therefore that a very large portion of that part of the surface of the earth now constituting Europe was covered with fresh water. In Westphalia, the Wealden is represented by a deposit 800 feet thick, consisting of sandstone and bituminous marl, with layers of coal and of ironstone and beds of limestone, the whole being characterized by fresh-water fossils. In Saxony, at Niederschöne, the formation is reduced to a deposit 40 feet thick, of dark-coloured sandy shale and marl, which is sometimes bituminous, and contains traces of coal, with an abundance of vegetable remains. Amongst these fossil plants only one shell has hitherto been discovered, but that is a most characteristic one, belonging to the fresh-water genus anodonta, which often prevails exclusively in muddy lakes and pools. The quadersandstein, or green-sand, overlies this deposit, and Cotta thinks it probable that the beds of this formation in Silesia,

which contain coal and the remains of plants, should also be allotted to the Wealden. Amongst the numerous reptiles of this epoch appear tortoises of genera which now occur in fresh water in tropical regions. The iguanodon, so called by its discoverer, Dr. Mantell, from its analogy with the living iguana, was a herbivorous reptile, and appears to have abounded at this epoch; and the same observer also recorded the existence of birds of the order Waders in Great Britain, but Mr. Owen has shewn that the specimens referred to were portions of a Pterodactyl. The nature of the fossil plants, and the number and magnitude of the reptiles, shew that the climate still continued tropical. Practically, the Purbeck limestone is well known, furnishing a lumachella marble; the designation lumachella being derived from the Italian word lumaca, a snail, and applied to those varieties of limestone which, with a granular or marble structure, abound in fossils. It requires caution in the selection of this stone, as much of it is not firm, and easily disintegrates, and in all specifications for its supply a sample should be referred to, in order to insure the delivery of the proper kind; a remark which may be extended in various degrees to almost every building stone. The sandstones are not firm, and whilst they give rise, from their wear, to very picturesque scenery, as about Tunbridge, are not durable. The clays produce a strong soil, as is evident in the rich district of the Weald of Kent.

CRETACEOUS.

Succeeding to the extensive fresh-water formation which has passed under review, comes a still more extensive and generally more widely diffused marine formation—the cretaceous. To bring this change more clearly to the mind, it may be well to imagine what would be the result, if, after ages of tranquil deposit of fresh-water detritus in the depths of the lakes of North America, a depression of the surface took place, by which it became, as the bottom of the lakes now is, below the sea level. Such a depression would cause, even if carried to a very moderate extent, an irruption of the sea over a large portion of the country, and marine deposits would immediately commence. If, again, after the accumulation of deposits, equivalent in thickness to the cretaceous, the whole mass were uplifted by the action of subterranean forces, the fresh-water deposits might be brought to view by the fracture and removal of part of the marine covering, whilst the remaining part of that covering might continue as a mural boundary surrounding them. In such a case, a strongly analogous result to that of the Wealden and chalk would be produced. Commencing at its base, the cretaceous system is sandy, and this division has been named the green-sand formation in England, the quadersandstein formation in Germany,—the names pointing to the principal peculiarity of the sandstone in each locality. In each it admits of further subdivision into upper and lower, the two being separated in England by a deposit of marl and clay, called gault; in Germany by one of marl, marly sandstone and limestone (the plänerkalk). But though there is in these divisions a striking conformity when viewed at particular localities (if, for example, the green-sand of England be compared with the quadersandstein of Saxony and Bohemia), considerable modifications appear in other localities. In Westphalia and North Germany, a conglomerate and a clay which Cotta considers the equivalent of the Specton clay occur below the lower quader; the pläner is replaced by a blue clay with crystals of gypsum, corresponding even nearer with the English gault; the upper quader is represented by a green-sand, which is surmounted by bright red marl. The sandstone of the Carpathian Mountains is also, as has been before noticed, referred to this epoch. On the Continent, there are likewise modifications as to the upper limit of the green-sand, the same lithological character, in sandy marls and sandstones, extending in Westphalia and North Germany high up into the upper section of the

cretaceous system; but such variations as these are only natural, being the necessary result of those local peculiarities which have already been so frequently adverted to. In England, the upper section of the cretaceous formation admits of a subdivision into the lower chalk without flints, and the upper chalk with flints, the whole reposing on the chalk marl,—a subdivision which is purely local. In Saxony and Bohemia, the whole section is reduced to beds of flints; in Westphalia and North Germany, the upper member, or the white chalk, is feebly represented, but all below it consists of chalk marls and sandstones, far more in character with the green-sand than with the chalk, though by their fossils proved to be the equivalent of it. In France, the Maestricht beds are at the summit, resting on the white chalk with flints, and from their peculiarities have been considered by some geologists to belong to an upper member, approximating the chalk to the tertiary strata, though their fossils are those of the white chalk, whilst the chalky character is carried downwards into the green-sand. All these modifications of lithological character must be anticipated by the geologist, and his skill is exercised in seeing through the obscurity to which they give rise, and tracing out the boundaries of sea and land, of bay and ocean, at each successive epoch. In doing this, he will sometimes find that the mineral conditions remain unaltered from one geological epoch to another, as is certainly the case in the Mediterranean, the Scaglia or white limestone with its flints having been in part deposited during the oolitic and in part during the cretaceous periods.

Few phenomena are more striking, or have engaged more attention, and excited more speculation, than the occurrence of long lines of flints in chalk. The marked contrast between the dark hue of the flint and the pure white of the English chalk, has without doubt led in the first instance to the special attention given to chalk flints, as the occurrence of silicious nodules similarly arranged is not confined to the chalk, having been noticed in the mountain limestone and in the oolite; nor is the arrangement by nodules always the prevailing one, as in the chalk of Ireland, for instance, extensive layers or beds are very common, as they are also in the oolitic and cretaceous portions of the white limestone of the Mediterranean.

The origin of chalk flints has excited much speculation, though it is evident from the preceding observations that the question cannot be confined to the chalk alone. A microscopic examination of the chalk flints has shewn that they contain numerous infusorial remains, and in consequence Ehrenberg was disposed to consider that they had been formed almost exclusively of such animals. On the other hand, the discovery of the texture of sponge in the flints has led others, at the head of whom is Mr. Bowerbank, to ascribe them in like manner exclusively to a spongeous origin; and a third party is more disposed to look upon the silica as having been held in solution by thermal waters, and either in solution or when depositing in a gelatinous state to have enveloped the sponges and other bodies it contains. It is highly probable that all these actions have contributed to produce the result observed; and when the observations which have been made on the peculiar affinity of silica for organic substances are considered, there can be little doubt that sponges have materially contributed to the production of chalk flints, though without being considered a necessary basis for all flints. As yet, the comparison of flints and cherts in various formations has not been carried out in a perfect manner, but it may be assumed as certain that they will be found to exhibit a material and characteristic difference in their zoological remains. Even to the practised eye the difference between the fragments of flints of various formations is perceptible, whilst they are commonly confounded together, as is the case with those spread out on the shore of our Southern coast, which are all called *chalk flints:* nor is this a

matter of indifference, as the determination of the prevailing currents may often depend on a knowledge of the true original locality of rolled flints.

In fossils the cretaceous system is peculiarly rich, the whole mass even of the white chalk, as has been shewn by Professor Ehrenberg, swarming with infusoria and other microscopic animals, in addition to the multitude of those of larger dimensions, as echinida, cephalopoda, &c. The spongiadæ and alcyonidæ are abundant: of the crinoidæ there is the peculiar genus marsupites; of the echinida, the genus ananchytes, and a profusion of species of many other genera; of the mollusca generally the remarkable genus hippurites, the true nature of which may yet be doubted, deserves special attention: the genus spondylus (plagiostoma and podopsis) has a very characteristic species in plagiostoma spinosum; the genus pecten affords in P. quadricostatus and P. quinquecostatus the type of a new genus; the genus inoceramus abounds; whilst of the cephalopodous division there are many most characteristic genera and species, such for example as the genus turrilites, a chambered shell with an external turreted form, the beautiful genus baculites, which unites a straight form with the sinuous septa of the ammonites, the hook-shaped hamites, and a great number of ammonites and nautili, producing in this order alone an assemblage so strangely different from that of our present tropical seas, where a single nautilus alone remains, as justly to excite our admiration and surprise. In fish there is a nearer approach to the existing epoch, as the genera squalus, galeus, and lamna occur; of reptiles, there is the peculiar genus mososaurus, and in England birds first appear. This is only a faint outline of a formation so interesting in England, though it may be considered a sufficient guide for the Engineer in other countries. Practically, the chalk hills are well known for their smooth outline and surface, and for the short herbage of their downs, so fitted for sheep pasture, whilst the marly beds of the lower portion of the system have long been known for their fertility, as specially noted by White of Selborne. In countries where the chalk is of a more indurated character, resembling the oolites, as in Greece, the tame character of its hills is changed to a far more bold and striking outline, resembling that of mountains of quartz rock. The value of the chalk for its lime, being easily worked and burnt, is well known, and though soft, it can be used as a building stone. The white limestone of the Mediterranean, partly chalk, is an excellent building stone, though, being brittle and hard, it is dangerous in such portions of military buildings as are exposed to cannonade. The flints, made up into a species of concrete and strengthened by stone quoins, were extensively used in the walls of ancient churches, and are still so applied; they are also used as a road stone, but being extremely brittle, and breaking with sharp cutting edges, they cannot be considered well fitted for such a purpose. In the lower part of the system, as exhibited on the Continent, the green-sand or quadersandstein becomes more practically useful than it is in England, though the soil proceeding from it is, on the other hand, much less fertile. In Saxony, the quadersandstein,—so called from its breaking into quadrangular portions,—is celebrated as a building stone, the colour being pure and good; and it is remarkable that the pläner (or gault) is there almost deficient, so that the upper and lower quaders are nearly in contact, and each yields its valuable bed of building stone. In other localities, as at the foot of the Schneeberges and in the Gottleube Valley, the existence of the pläner is known from a line of water springs which it throws up; and this fact is noticed here as illustrative of the theory of springs, which will be again referred to at more length. Westward, the pläner, which had almost thinned away, takes an unusual development, stretching up into and occupying the place of the upper quader, which is there wanting. Such variations as these are most instructive to the experimental geologist in his practical applications, and the character of the deposits is also

well displayed in the German districts which have been described. In the valley of the Elbe, the boundary hills are of granite and syenite, as the bottom of the valley itself is at Meissen; and yet in boring at Dresden a depth of 856 feet was passed through without arriving at the granite. If now we could imagine this accumulation of quadersandstein and plänerkalk to be removed, and the basin containing it laid bare and then filled with water, an inland sea would be formed, the bottom of which would be more than 500 feet below the present sea level, and the surface of its waters about 300 feet above; but the sandstones and limestone were evidently a marine deposit, so that after an epoch when in countries not very distant from it land plants were growing, and an extensive fresh-water deposit forming, this basin must have been depressed more than 300 feet below its present level, and though now it would be a lake, if filled with water instead of mineral matter, it was then a deep hollow in the sea. Here, then, is another of those surprising results, similar to that pointed out in the Wealden, which geological research has made known.

TERTIARY CLASS OF FORMATIONS.

At this period of geological history, glimpses are obtained of the present order of creation, animal species which still exist appearing amongst the relics of the past. This circumstance throws over the tertiary strata a high degree of interest, and it has been made by Mr. Lyell the groundwork of his subdivision of them, the terms adopted signifying, as it were, the dawning and gradual progression of the existing light, and the basis of subdivision being laid on the proportional number of existing species, as shewn in the following Table, extracted from his 'Elements;' a principle of classification which is, however, much disputed by some philosophers.

Periods.	Localities, &c.	Per centage of recent species.	Number of fossils compared.
Post-Pliocene ..	Fresh-water of Valley of the Thames	99 to 100	40
Newer Pliocene.	Marine strata near Glasgow	85 to 90	160
Older Pliocene..	Norwich crag	60 to 70	111
Miocene.......	Suffolk, red and coralline crag....	20 to 30	450
Eocene........	London and Hampshire	1 or 2	400

The consideration of this Table naturally gives rise to this remark, that the two lower subdivisions are more soundly established than the upper, as the comparison is made upon large and nearly equal numbers, so that the discovery of a very considerable number of recent species would be necessary to affect materially the comparison; whereas in the upper, the numbers are so much smaller, and so unequal, that the results might be materially disturbed by the discovery of only a moderate number of recent species. It is necessary also to bear in mind, that in approaching the existing epoch, and the organic constituents of the present creation, it is only natural to expect that evidences of similar physical conditions should be discovered; and as the fauna and flora of various parts of the present world are widely different from each other, so also must have been those of different localities, in periods which exhibit so much of the zoological characters of the present. In determining, therefore, the exact place of a deposit in the series of tertiary formations, the comparison of fossils should be made with the recent species of the neighbouring coasts and seas, the fauna and flora of each local deposit becoming, as it were, independent, just as the fauna and flora of many recent localities are. On this principle, so well explained by Mr. Lyell, the contemporaneous fossils in deposits of each tertiary epoch, and specially in the more recent, may, at various parts of the earth's surface, have scarcely any

resemblance to each other, although in each locality conforming to the general rule of a growing approach to the recent types. The tertiary formations must therefore be considered as made up of many local formations, the exact mutual relation of which to each other it is sometimes very difficult to determine. The marine and fresh-water beds appear to have been deposited in extensive basins, and it is remarkable that the great cities of London, Paris, Mentz, and Vienna, have been founded on such ancient basins. The great brown coal formation, however, which is spread over a large portion of Germany, and abounds in land plants, does not appear connected with a basin sufficiently marked as by any depression of its surface to explain so deep an accumulation of vegetable matter as may be seen, for example, at Zittau in Saxony. In general, the tertiary deposits of England do not attain any great terrestrial height, no very material elevating force having been exerted beyond what was necessary to raise them partially above the seà level; but along the axis of greatest movement, both in Europe and America, the case is different, the Nagelflue of Switzerland, with its brown coal and limestone, skirting the Alps in a chain of mountains 6000 feet high, the thickness of the deposits being 2000 feet. Such deposits are very widely spread, occurring in North and South France, in the South of England, as also, in its upper members, in Scotland and Ireland, in North Germany, and along the Rhine in Middle and South Germany, on both slopes of the Alps and Apennines, in Sicily, on the coast of Africa, and spécially on the shores of the Mediterranean, in Poland, in North and South Russia, in North and South Asia, as for example in the Bay of Bengal, in the East of North America, and in Equatorial America, &c.; so that in almost every part of the globe traces have been found of that gradual approximation to the present physical and zoological conditions of the earth's surface, which is learned from the study of tertiary deposits. The general evidence, especially in Southern regions, of the fossils, must necessarily be towards the existence of a tropical climate within this epoch, the divergence from such a climate being as yet small in such positions, except where, as in Switzerland and South America, it has been augmented by elevation of the surface from internal disturbance; and this fact alone would be sufficient to prove that the climate of such localities is comparatively very recent, the elevation having taken place at the very threshold of our present epoch.

In a few Northern localities, however, it is supposed that there is a tendency in the evidence towards a colder climate within the later tertiary epoch; nor is this unnatural, as in that portion of the earth which approaches towards a region of low mean temperature, a very slight modification of the terrestrial surface might have been sufficient both to depress the mean, and to check those variations to a higher summer temperature which must materially affect the growth of all animals possessing the power of even partial locomotion.

EOCENE AND MIOCENE.

The English tertiary deposits are only important in the lower members, and in them are very local. The basins of London and Hampshire are the lowest geologically, and belong to the eocene period. They are bounded and underlaid by the chalk, and their strata consist of sands, clays, and gravels. On the variation of mineral character, a subdivision has been founded into the upper sand or Bagshot sand, the London clay, and the plastic clay, which consists of alternating beds of clay, sand, and shingle; but as such peculiarities must be considered purely local, and are not here augmented in importance by any important zoological differences, they cannot be adopted as a sufficient basis for geological classification, though within the districts of great practical use, as will be seen in treating of the subject of 'Springs.' In the shells there are several nautili and others of a tropical type, and many also in the plants, more

than seven hundred of which are supposed to have been discriminated; and again in the reptiles, the teeth and bones of many crocodiles and turtles, and even the bones of a large serpent, have been found. The remains of a bird, of various quadrupeds, and of a monkey of the genus macacus, all correspond in this testimony to a warm climate. Though corresponding in epoch, as shewn by its assemblage of organic remains, to the London basin, the deposits of the Paris basin are singularly different, being composed of a coarse white limestone, calcaire grossier, a silicious limestone with beds of crystalline gypsum and of flint and marls with some clay and lignite. The chalk basin, which is thus filled up, is very extensive, being 180 miles long and 90 miles wide, and when first described accurately by Cuvier and Brongniart, was supposed to embrace the whole series of tertiary deposits, and to be subdivided into several distinct formations; but more recent examination has led to a different conclusion, and the several variations from marine to fresh water are more reasonably accounted for on the principle of the discharge of fresh water with its deposits into an extensive gulf. This modification has brought the two basins of London and Paris into geological connection with each other, and, as might have been expected, fresh-water deposits are also found within the area of the London basin or gulf, as at Headon Hill and Binstead in the Isle of Wight, many of the quadrupeds of which locality correspond with those of the celebrated Montmartre gypsum quarries which were the classic ground of the great Cuvier's wonderful researches and discoveries. Practically, the great mineral difference in these deposits in the two basins must give rise to similar differences of application. The clay beds of the London sometimes abound in nodules of a calcareous stone, used for making Roman cement. These nodules often contain marine shells, and sometimes the remains of turtles and fruits. When traversed by cracks and veins dividing the mass into parts, as by septa, they are called septaria. Harwich and the Isle of Sheppy are well-known localities of these nodules. In the Paris basin, the calcaire grossier furnishes, in some of its varieties, very good building stone, and the silicious fresh-water deposit yields an excellent millstone. A careful microscopical examination of the flints of the Paris basin and of those forming the shingle of the London basin, as compared with the true chalk flints, is yet a desideratum, and may throw considerable light upon the direction of the drift during this period. Mr. Prestwich has made an important alteration by proving the true London clay, including the Bognor clay, to be more ancient than the calcaire grossier, and therefore to correspond with the sands, &c., of the Paris basin: he discovers, however, in part of the Hampshire series, the true equivalent of the calcaire grossier. The range of the London clay has been extended through a large portion of the N. E. of Europe by Dr. Girard, of Berlin.

The miocene epoch is represented in England by the Suffolk crag, which is subdivided into the coralline crag below and the red crag above. The coralline crag is very local, and is generally calcareous and marly, being a mass of shells and small corals, whilst the red crag is a highly ferruginous grit. Although the thickness of both members of this deposit is really very small, not together exceeding 60 or 70 feet, the number of fossils it produces is very great. Mr. Searles Wood had obtained in shells alone 230 species from the red crag, and 345 from the coralline, 150 of which were common to both. There is a considerable difference in the proportion of recent shells in the two divisions, and as the lower had been worn and disturbed before the deposition of the upper, they exhibit the striking modification which has been consequent on the change from a coral reef to a shingle bottom; and this example may be cited, with many others from all parts of the geological series, to illustrate the history of existing coral reefs, as they distinctly shew that it is not necessary to suppose that such reefs are of great thickness, the product of almost

infinite ages, or that they rest on the peaks of submarine volcanoes; since now, as in the ancient epochs, a growth of coral may have commenced on a sand or mud bank, have been interrupted by a new deposit of a similar kind, and then again renewed, such alternations being specially frequent in the carboniferous period.

The shelly sand and marls of the celebrated faluns of Touraine have been allocated to this section of the tertiary deposits, though if compared with the crag there is a considerable difference in fossils. Taking each, however, as an isolated deposit, there is the same proportionate number of recent species, and on this ground they have been placed in the same division, a system of reasoning which will probably be extended hereafter more widely. The deposits of Piedmont, Lisbon, Styria, and Mayence, though connected by characteristic fossils with this epoch, exhibit each its peculiar modification of mineral character, and there are also some detached lacustrine deposits in Italy, rich in the remains of mammals; but the molasse of Switzerland, from which the Germans call the whole tertiary class "molassen," specially deserves notice. It is a vast mass of a soft sandstone, which probably belongs in part to several portions of the series, and it derives its name from the ease with which it is cut in the quarry. The fossils are local, but have hitherto tended to place the deposit in this section.

Practically, the formation varies in importance in different districts. In Suffolk, the coralline crag yields a soft building stone, and the marls are useful as manure. In the Styrian Alps, limestones of a coralline and of an oolitic structure are largely developed, and the molasse, from the ease with which it is cut, is also valuable.

PLIOCENE FORMATIONS.

It is unnecessary to dwell long on the upper or newer pliocene formations, as they are very feebly represented in the British Islands, being confined to minor deposits of sand, gravel, and clay. On the Continent, however, (and this is quite consistent with the theory of the gradual progression southward of geological formations,) they become very largely developed, in Sicily extending over nearly half the island, and attaining an elevation of 3000 feet, being composed partly of calcareous and partly of argillaceous strata, and exhibiting by the occurrence of recent species of shells amidst such a mass of stratified matter, a striking proof of the accuracy of geological reasoning as regards the older formations. The older pliocene in England is supposed to embrace the Norwich crag, which was formerly confounded with the coralline and red crag of Suffolk. In Italy, the Sub-Apennines are again a striking exemplification of the great development of these comparatively recent strata, and the blue clay of the Mediterranean, rising sometimes to the height of 1000 feet above the sea, is also of this epoch. The thickness of the Norwich crag, consisting of sand and loam, and considered an estuary deposit, is small, about 40 feet, and the newer pliocene is also insignificant in vertical extension. In Sicily, the newer pliocene, though so vast, is still marine in character, but in Russia the singular phenomenon is again observable of an equal extension of fresh-water deposits, a vast mass of argillaceous limestone occurring around the Caspian, which Sir R. Murchison calls the Aralo-Caspian, or Steppe limestone. The univalve shells of this deposit are of fresh-water origin, and are associated with bivalves, which are common to partially saline or brackish water, but there are no corals, so that the true characters of a deposit in an inland sea are fully exhibited. The thickness of this supposed member of the pliocene is in some places between 200 and 300 feet, and it attains elevations of 700 feet above the present level of the Caspian. It is remarkable that whilst the species of testacea of the newer pliocene formation were nearly identical with those of the existing period, there should still have been so marked a distinction in the animals of a higher class,

as is seen in the bones of the various celebrated bone caves and ossiferous breccias of all parts of the globe, a difference which extends even beyond the limits of the pliocene. There is also this remarkable fact, that whilst in the old world the general type of such elevated organisms is in conformity with that still existing, though indicating the extension of the animals now confined to warm climates far northward of their present limits, there is in that singular country, Australia, a type peculiar to itself, and extending back to this period; so that it may be assumed that in the tertiary epoch this vast region was already isolated from the rest of the world: and is it not almost allowable to imagine, when the degraded character or type of its population is considered, that man is even there a relic of pre-existing creations?

In India, much has been done by our brother Officers of the Indian Army, Major Cautley and Dr. Falconer, to elucidate the natural history of this epoch by collecting and describing the bones of extinct animals; and Captain Vickary has very recently shewn, that in the Beloochistan Hills a large assemblage of beds of sandstone, of conglomerate, of clays, and of bone gravel, belong to the tertiary formation, the base on which they rest being a nummulite limestone; and when the difficulties attendant upon an Eastern climate are considered, such exertions may well be a stimulus to those who are serving in climates more favorable to physical exertion.

The connection of the ancient lava currents of Auvergne with the tertiary strata has already been noticed, but it requires a few additional remarks. The age of the stratified deposits of the country is considered by Mr. Lyell to be generally eocene, although some portions may possibly extend upwards to the miocene. The base of this system is granite, and therefore either eruptive or metamorphic of a more ancient date. If then the deposition of these strata had ceased, and the surface been upheaved prior to the later members of the tertiary period, the evidence of a former though still continuing wear might yet be found, as the general effects of river action combined with lava currents, afford in this singular country many proofs of the lapse of a vast extent of time, during which the physical features of the district had been only modified by sub-aerial agencies. In Plate IV. fig. 24, Lyell's figure of successive gravel beds which represent alluvions of different ages, covered by lavas, exhibits these phenomena; and his still later inquiries have shewn that in the Valley of the Couze at Nechers, the lava current of the Puy de Tartaret has passed over a red sandy clay, rich in the bones of mammalia, which are associated with some of reptilia and of birds, and with several *recent* land shells. The bones, though closely allied to those of recent species, are considered distinct, and include the equus fossilis of Owen. Mr. Lyell, from the superposition of the lava, is enabled to affirm that the bone beds, in whatever way the animals were destroyed and their relics so imbedded, belonged to the alluvial formations of the river bed and river plain at the time of the flowing of the lava of Tartaret; whilst he shews, from the existence of an ancient Roman bridge, not more recent though probably much older than the fifth century, which spans with two arches the river Couze, abutting on both banks against the lava which had thus been cut through and formed into the present existing ravine fourteen centuries ago, that as respects the events of human history, the lava of the Puy de Tartaret was at least of great antiquity. On the whole, Mr. Lyell considers this lava to be a type of the products of the most modern volcanic eruptions of Auvergne, and to be referrible either to the close of the newer pliocene or to the post-pliocene period, a period when, as before noticed, "the mollusca were identical with those now living, although a great many of the mammalia belonged to species now extinct." This recurrence of alluvions and even of ossiferous beds, with overlying streams of lava, deserves the attention of the few, who, from reasons not geological, would still consider the stratified deposits of the earth as the work of one great flood, as it is

utterly impossible to reconcile such volcanic eruptions to so limited a theory. In a practical point of view, it has already been shewn that in countries where the tertiary strata are fully developed as either deep sea or great lacustrine deposits, they supply valuable building materials both in limestone and in sandstone; and it may be also stated that the celebrated Carrara marble, once considered primitive, belongs to the tertiary epoch. The fossil bitumen so extensively used in asphalte pavements, namely, that of Bastenue, a small village of the South of France, 15 miles north of Orthez, is tertiary. The basis of the formation in which the bitumen is found is a sandy limestone, which has been allocated to the cretaceous system. The overlying beds are variously coloured sands and clays, which are 50 or 60 feet deep, and covered by gravel and sand, which extend many miles in every direction. The beds are usually horizontal, though sometimes much disturbed by the intrusion of igneous rocks. Under about 45 feet of the variegated sands and clays, the bitumen appears in small quantity in a bed of blackish sand, 4 feet thick. From 5 to 15 feet of bitumen are then observed, the upper part consisting of a mixture with loose and coarse sand, the lower being more compact, and mixed with finer sand. In some places, from 10 to 15 feet of sand, without bitumen, occurs, whilst in others the bituminous sand is thicker, and rests directly on the secondary sandy limestone. In two localities, marine shells have been found in the bituminous sand, and Mr. Pratt refers them to the miocene period. The shells are arranged in layers, and are quite perfect, the valves not being separated from each other; and the bitumen, when in a soft or liquid state, was, in Mr. Pratt's opinion, forced into the shells, after their deposition in the sands in which the animals lived, as even the smallest cavities are filled. The eruption of the bitumen is supposed to have been connected with the appearance of the ophite, an igneous rock which has produced such great changes in the Pyrenees. The bitumen is easily cut when first exposed, but in a few days it hardens so much as to become incapable of purification: the purification is effected by boiling the sandy mixture in a large quantity of water two or three times, when, by continued and careful stirring, the sand gradually settles to the bottom, while the pure bitumen rises to the surface and is taken off. A small portion of bitumen occurs in the tertiary rocks of Anti-Paxo, and again in a larger quantity at Zante. An inspissated tar or pitch of probably a juniper is used for similar purposes in the Morea, and has been tried with tolerable though varying success at Corfu. A large quantity of coarse sand is mixed with the tar when heated, so that it forms a bituminous concrete. The variableness of the result, from the different qualities of the crude material and the difficulty of manipulation, is against the value of this material; but it is probable that were the process of nature imitated, and the crude tar subjected to long boiling, and after being forced into a mass of heated sand, treated as the fossil bitumen is, it would be found nearly equal in quality.

The existence of gypsum and salt in the tertiary strata has been already noticed.

QUATERNARY OR POST-PLIOCENE.

Our inquiry has now come to that point, where on one hand we still see in the recent results of geological phenomena evidence of the formative processes of nature,—coral reefs still rising from the depths of the Pacific,—conglomerates being still formed in the Mediterranean,—beds of marl being still deposited in lakes,—travertin being deposited from mineral springs,—and peat being observed to have formed over fresh-water shells, the bones of land animals, and even the works of human art (in one instance, in the county of Galway, an ancient hut with a paved passage having been laid bare by the removal of peat 30 feet deep); and, on the other hand, we are still kept at a distance from the recent epoch; for although the shells found are all

of recent species, they are generally arranged in positions and associated with detritic matter of such a description that their appearance indicates the action of forces prior to the present order of things. These masses, the true post-pliocene, though now exposed to view and frequently found at high elevations and of great depth, have evidently been, like the antecedent formations, under the level of the waters of either lakes or seas, whilst the recent strata must necessarily, in most cases, be yet in the position from which the former have emerged. The beds of sand and gravel spread over so large a portion of the earth have always attracted attention, and for a long time were considered so many results of the passage of the diluvial waters over its surface; but a rigid examination of the peculiar characters of these deposits has shewn that such an opinion is untenable: for example, they are sometimes found to consist of deep beds of sand, separated by fine clay partings into a multitude of beds; sometimes they are composed of alternating layers of sand and gravel, some of which, as shewn in Plate III. fig. 14, exhibit cross lamination: sometimes they consist of clay with imbedded boulders of various rocks, and of various sizes; the term boulder being properly applied to rolled or round masses; sometimes they contain marine shells, sometimes bones, and sometimes they extend over large spaces and occur at great altitudes and of great thickness, without any trace of organic bodies. Many marls and clays or silt, with land and fresh-water shells, belong to this division. When the various circumstances attending such deposits were considered, it became evident that they could not be brought within the sphere of action of any one great wave, or even within the action of tumultuous waters, continued only through a very limited time, and it became necessary to seek an explanation by classing them with the ordinary phenomena of nature. That the substances forming these deposits have been broken up, triturated, and moved by water, cannot be doubted, and the term drift therefore has been applied to many of them; but of course though all such matter and substances have been more or less drifted, the distribution of them must have been modified by many local peculiarities, giving rise to deep deposits of sand in one place, and to long continuous banks or shoals in others. That such modifications of recent drift are now taking place, the sounding lead sufficiently declares; and it is easy therefore to apply the same reasoning to ancient drift. One great progressive step has been only recently taken, by separating the great 'erratics,' or those large angular masses of rock which are often found resting on the surface of sand or gravel, from the beds on which they rest, and thus distinguishing them from the rounded boulders, which are sometimes connected with the latter, and at others heaped up with clay as deep accumulations in hollows.

It would be impossible to detail here all the peculiarities of such deposits, sometimes assuming, as shewn in Plate III. fig. 14, great regularity, the boulders being generally at the top, and at others exhibiting a confused mass; but the reasoning on which the theory of the distribution of such sand, gravel, boulders, and of 'erratics' rests will be readily understood from an abstract of Sir R. Murchison's 'Papers on the Detritus of Sweden.' That able observer having, in his work on Russia, discussed the well-known phenomenon of the long lines of detritus, dotted here and there by 'erratics, or angular fragments,' which stretch from the Northern regions into Poland and Germany, proceeds to examine the circumstances of the detritus in Sweden, including Gothland and Dalecarlia. In Scania, the most southern province of Sweden, or that most distant from the great source of the erratics, the fundamental rocks are chiefly cretaceous, and they, together with two detached hillocks of the oolitic period, are covered with detritus of sand, mud, and *rolled* northern boulders, angular superficial blocks being rare: but here, amidst these worn and travelled fragments, occur, and in Sweden only here, the remains of great land quadrupeds; so

that Sir R. Murchison infers, that though the more northern portions of Sweden may have yet continued under water, this portion, like the continent to the south, must have been raised above the waters, and inhabited by such animals either just before or contemporaneous with the existence of man; this latter inference being principally founded on the researches of Professor Nilsson, who extracted a perfect skeleton of the bos urus, or B. primigenius, from beneath ten feet of peat, the horns of the animal having been deeply buried in the subjacent blue clay, and on close examination discovered in the vertebral column a perforation which corresponds exactly to the form of wound which would have been inflicted by one of the stone-headed javelins of the aborigines of Scania. Professor Nilsson strengthens this deduction by the existence, of which he considers he has proof, of bogs containing these land animals, and even affording evidence of the co-existence of man, which have since been submerged and covered by gravel and sand; and Sir R. Murchison considers the bogs of Scania as a parallel case with those of Ireland, under which the remains of the great fossil elk, Megaceros Hibernicus, are buried; although the real parallelism of the two cases can scarcely be admitted if it be considered sufficiently proved that the bogs of Scania have actually been covered by marine drift. Leaving aside this obscure point, and proceeding north and east into a more elevated district, the materials of the northern drift are observed to be arranged in linear directions, forming great traînées, which, however, are not so strikingly developed as in the 'Osar,' or longitudinal zones of gravel of Central and Northern Sweden. Traversing the country towards Christianstad on the east, a ridge of gneiss on which some 'erratics' rest, a tract of sand, ten miles wide, without a single large block, is met with,—then at intervals traînées of gravel with blocks, and on nearing Christianstad, sandy hills are observed, which rise 300 feet above the plain, and have on their summits clusters of angular blocks, whilst such erratics are rare in the plain itself below them, (see Plate VII. fig. 35.) In some of these hills, where subsidences have occurred, vertical thicknesses of sand layers are seen, 40 feet to 50 feet thick, beneath the great blocks, all of which are more or less angular, and some of them 8 feet to 10 feet in diameter. Sir R. Murchison here observes, that these sandy accumulations, from their form and silicious texture, have all the appearance of having been fashioned by currents of water, whilst they are surmounted by isolated groups of angular blocks, which, from their composition, must have been derived from the countries on the north (the substrata to the south being entirely different), and transported across the wide low tracts which lie around Christianstad. Proceeding further northward, and finally into Northern Sweden, the phenomenon of long traînées is still more strikingly exhibited, whilst the rocks are worn down in undulating surfaces, and examples are exhibited of rounded northern and abrupt southern sides. It is unnecessary to pursue these details further, and it may be therefore generally remarked, that the superficial detritus, so long called diluvium, exhibits itself in several distinctive phases. 1. That of deep beds of sand, not heaped up in one mass, but manifestly deposited in successive layers, and therefore, though doubtless triturated by the action of water, and even moved along by currents, to be considered as comparatively tranquil and regular deposits. 2. Lines of gravel and of gravelly clay with rounded boulders, which sometimes surmount the more quiet deposits, and by their definite direction in such traînées for even hundreds of miles, indicate the action of powerful currents, moving in Northern Europe, in a slightly divergent direction from the Scandinavian Mountains to the south on one hand, and from the south to the north on the other; this latter remarkable fact being the result of Sir R. Murchison's recent inquiries, and seeming to indicate that the transport was not effected simply by the usual submarine currents flowing from north to south, but partly, at least, by

undulations of the bottom, which caused powerful waves of translation in all directions from the axis of disturbance. 3. 'Erratics,' or large angular blocks, which are found not immersed in the sand, mud, or gravel, but resting on its surface, or on ridges of rock where there is no such superficial covering; and that it has been impossible hitherto to adduce any sufficiently satisfactory cause of the translation of such masses, which, having preserved their angles, cannot have been exposed to the rolling action of water, other than that of moving ice. 4. In the preceding cases, the detritus is supposed to have been foreign, or to have travelled; but it is very often in part local, and then indicates the wear of the adjacent rocks, both by the direct action of the sea against them, and by its power of attrition in moving fragments along a coast or a bank. Where both forms of detritus occur, great care should be exercised in discriminating between them, and determining which of the two is the underlying or overlying. 5. Connected with this question is the phenomenon of what have been called raised beaches, although it must not be supposed that each of these has actually been a beach, in the ordinary sense of that term. Mr. Smith, in tracing the successive upheavals which have given to the Rock of Gibraltar its present form, notices several modern detritic beds which contain recent marine shells, and occur at various heights up to 700 feet above the present sea level. Some of these beds are connected with ancient sea-worn caves, and would be therefore justly classed with the effects of a sea beating against a beach and cliff: but if the phenomenon be observed more extensively, it will appear at least possible that some such deposits are merely forms of current drift, and were not, strictly speaking, beaches. Sir R. Murchison, in the statement of his hypothetical views respecting the condition of Gothland, from the period of the consolidation of the Silurian limestone which forms its basis, may be quoted as illustrating this subject. He there supposes the ancient limestone to have been eroded, whilst yet beneath the sea, by ordinary marine action; but it has been justly observed, that this description of action is as yet little more than conjectural. He then supposes this limestone exposed to powerful denudation, by the passage over it of heaps of fragments of crystalline rocks drifted from the north, and impelled forward by powerful waves of translation, according to the theory of Mr. Scott Russell and Mr. Hopkins, by the wearing action of which the exposed northern face and the summit were, it is supposed, broken, polished, grooved, and striated, whilst the drifted rollers were shot over the southern escarpment, and lodged at its foot, there forming a bank of gravel, without wearing away the lee or protected side of the still submarine hillock. The waves of translation having subsided, a glacial or ice-floating epoch supervened, during which ice-bergs and ice-flows transported large angular blocks, and deposited them sometimes on the surface of the denuded limestone, and sometimes on the water-worn gravel or Osar, and at length, the island having been uplifted above the level of the sea, it would exhibit traces of these past actions in its worn northern face, in its summit cap of gravel surmounted by angular 'erratics,' and in the gravel bank at its southern base, which would *then become* a beach. New elevations would raise the island still higher, and now, by the action of the waves against its surface, *local* gravel would be formed of the fragments of the limestone, and real beaches be fashioned out of it.

It is unnecessary to pursue these speculative details further. Similar phenomena have been observed in America, and whilst in Europe the boulder formation has been traced southward to the 52° of latitude, in America it has been observed to extend to the 38½°;—to be occasionally more than 200 feet thick, and to bear on its surface vast 'erratics;' one, a block of greenstone, 100 feet in circumference, having been noticed by Mr. Lyell on the summit of a high hill of sandstone,—the largest European erratic is on the Island Fohnen, and measures 44 feet across,—whilst

the surface of rocks, when laid bare, are observed, as in Europe, to be striated, furrowed, or smoothed. The universality of these phenomena in a space extending from the northern elevated districts towards the south, assuredly points to some general force, such as that which now effects the transmission of the Polar waters to the Equator, and although such an action may be aided by the waves of pulsation consequent on the elevating forces, it seems difficult to account for the effects by these latter forces alone. Further, as the 'erratics' pursue a similar direction with the long traînées of gravel, they shew that the currents preserved their general direction for a long period of time, and that such direction was in conformity with that which the present course of icebergs exhibits. Sir R. Murchison, however, points out that to the north of the Scandinavian chain, the 'erratics' have moved to the northward; but has their extension in that direction been traced sufficiently far to remove them from the possible action of glaciers? Finally, in considering or discussing these, or indeed any geological phenomena, it must be remembered, that though one particular set of causes may be demonstrated to have been in action by the evidence of one class of facts, such proof does not exclude the co-existence and co-operation of other causes, and that the only way of obtaining a satisfactory solution of the phenomena is the consideration of all such causes. It is thus, that whilst the discovery of marine shells under or in the transported gravel in so many localities indicates that a large portion of the earth's surface over which it has been distributed was then under the sea, it does not preclude the possibility of currents in large lakes, such as those of North America, produced by the out-draughts of large rivers, and carrying with them masses of ice, loaded with gravel, and perhaps surmounted by erratics: that whilst it seems impossible to account for the transport of such huge masses of rock, and for the angular condition of erratics by any other transporting force than that of ice, it does appear unphilosophical to exclude either form of that force, as the one seems only a necessary result of the other, but reasonable to assume that the glacier must have co-existed with the floating sheet and berg of ice, and co-operated in transporting the fragments of rocks by land and sea: that though the great extension of 'Escars' and 'Osars' indicates the action of currents through a very great space, the elevatory forces may have produced waves of translation during the same epoch, and given rise to the formation of radiating lines of gravel, and by the modification of the usual action of currents, have at the same time led to the deposition of 'erratics' upon them: that, whilst currents and their accompanying floes and bergs of ice may have formed submarine banks of gravel, and glaciers have produced their 'moraines' or terrestrial banks, many a deep recess or steep submerged valley may have been filled up, either with sand, gravel, or mud mixed with rolled boulders; or, in short, that all the causes which in the present state of the earth are known to co-operate in producing those changes and those results which may possibly become the matter of inquiry to future intelligent beings, did co-operate in the period now under discussion, to produce the results which have been classed under the general term diluvial, and which are now called quaternary, post-tertiary, or glacial. The term glacial, which has been recently applied to this formation, is derived from the numerous manifestations of the action of ice over large spaces; in the wearing or striation of rocks, in some cases even on their under or overhanging surface; in the transport of erratics; and in the apparently sudden destruction of the numerous large animals now peculiar to warm climates, which are found either in the gravel itself or in caves partially closed by it, or frozen up in the ice; and as the general evidence as to climate, according to Dr. Philippi, after balancing the exceptional cases on the one hand with those on the other, indicates little difference between the latest tertiary and the existing epochs, such destruction

seems to indicate that suddenly depressed temperature which, whilst it destroyed many animals still fitted for warm climates, gave rise to a large extension of glaciers on land, and to a widely extended spread of floating ice on the sea,—agents not apparently in existence during preceding epochs in which erratics did not occur. To elucidate still further this highly interesting subject, our Officers at distant stations are earnestly requested to collect information as to the nature of the loose materials on the surface of the earth,—to ascertain whether they are the débris of local rocks, or have come from a distance,—and if the latter, to determine their native localities, and the physical features of the countries over which they must have been transported.

RECENT OR ALLUVIAL.

Having now entered within the still passing period of the earth's history, our object will be to direct attention to those phenomena which, as they can be now studied in their progress and changes, are the more valuable guides to us in estimating the character of the past, since we discover in the alluvial deposits, through many analogies, the mode in which more ancient deposits have been formed. It is now that the action of rivers may be traced, the extension of the deltas at their mouths estimated, and the action of the sea itself observed in all its phases. The processes of destruction and of formation connected with these actions extend over the whole earth, though, as they are necessarily modified by many local peculiarities, the result is not identical but parallel formations, the contemporaneity of which it might be difficult at more remote ages to determine. This class of formations may, from their peculiarities, be divided into mechanical, chemical, and organic, and further into land and sea formations, the results of volcanoes being partly connected with each.

Mechanical Deposits. First in valleys.—Torrents and rivers, in their course through mountain regions, carry along with them a mixture of large and small fragments, torn from the projecting boundary rocks, and deposit their load in the lower and more tranquil portion of their course, as gravel, sand, or mud,—the nature of the deposit being modified in proportion to the strength of the current, as is also the distance to which it is carried; so that the rolled fragments, or gravel, which at a period of high floods are hurried down a considerable distance, are at ordinary times covered with fine sand or mud; and there is therefore in this simple and constantly occurring natural event, an exemplification both of the removal of portions of rocks from their native bed and their deposition at another, and of the formation of alternating beds of clay, sand, and gravel. When the rivers or streams pass through lakes, or wide expansions, matter is always deposited at their bottom; and when circumstances expose such deposits to view, it is sometimes possible to distinguish between the portion or layers produced in a peculiarly wet season, when the force of the torrent would be in excess from that of a dry season, and even to separate the portions deposited in the dry and wet seasons of the same year. When the direction of the river is through rocks rich in ores or in precious stones, the action of its waters often separates them from their matrix, and as the weight of such substances is generally greater than that of ordinary mineral matter, a partial separation is effected, as they remain behind, whilst the finer matter is hurried onwards. On deposits of this kind, which become valuable from the quantity of ore or of gems which they contain, works are established for repeating the natural process, by again washing away the remaining fine matter; and in this manner, the weight of the substances sought, effecting, as before their separation. Particles of gold, platinum, iridium, rhodium, palladium, osmium, chrome, and magnetic iron,

are obtained in the Ural chain of Russia and in Brazil, and of gold in Wicklow and elsewhere; the term stream gold or stream tin, &c., being applied to such products. As yet, platinum has only been obtained in this secondary manner, and the greater proportion of the gold is similarly procured, as well as a considerable part of the tin, whilst the zircon of Bohemia, the chrysoberyls and hyacinths of Ceylon, the diamonds of Brazil and of the East Indies, are due to similar separation and deposition; so that mankind is indebted to these newer operations for much of their direct wealth, as well as for that which springs from the fertility of the soil, restored by the overflowing of rivers charged with mineral matter, as in the well-known case of the Nile. In Borneo, gold has been found mixed with alluvial matter in limestone caves. The gravel of the Rhine is estimated by M. D'Aubrée to contain an amount of gold equivalent in value to 165,828,000 francs, or £6,564,025.

Mechanical Deposits.

Deltas.—Where rivers discharge their suspended mud into the sea, and where the coast is shelving, and there is no powerful marine current, a delta is often formed by the deposition of mud at the point where the waters have lost their transporting power. This class of deposition usually commences at the centre of the river's mouth, and an island is first formed, which goes on extending and widening till a triangular space is occupied by the deposit, the apex being directed upwards, and the base facing the sea; and this peculiarity of form having been first specially noticed in the mouth of the Nile, the deposit assumed the name of Delta, from the Greek letter of that name. Sometimes, as in the Nile and the Rhine, several islands are simultaneously formed, so that the delta is finally a compound one, and is separated by various channels. The delta of the Ganges is still more remarkable than that of the Nile and Rhine, its perpendicular depth from the apex to the base being about 180 miles, and therefore exhibiting a formation comparable in extent to many of those of past geological epochs.

Mechanical Deposits.

From the action of the Sea.—As the rivers, so does the sea itself effect a change in the form and position of the land with which it is in contact; for, whilst at one point its waters encroach and carry away, at another they deposit and increase; and as they contain from three to four per cent. of various mineral salts (as chloride of sodium, chloride of magnesium, sulphate and carbonate of magnesia, sulphate and carbonate of lime), their resulting formations are often more fixed and solid than those of fresh water. This is specially the case in warm climates, and as the fragments of shells are often mixed with the deposits as well as comminuted portions of calcareous rocks, there are sometimes formed sandstones, sometimes limestones, sometimes conglomerates. It is in such a formation at the Island Grande Terre, near Guadaloupe, that human remains have been imbedded, and there cannot be a doubt that many such are in progress below the waters of the sea, and only to be brought to light by such upheavals of the coast and sea bottom as that which affected so strikingly the coast of Chili.

Chemical Deposits.

Calc Tuff and Calc Sinter, or Travertin.—Where mineral waters come to the surface, and as they pursue their course along it, by the influence of light, air, evaporation, loss of temperature, absorption, and escape of carbonic acid, a mineral deposit is thrown down. Springs charged with lime yield in this manner calc tuff, or sinter, which, according to the researches of Gustav Rose, assumes the form in cold springs of calc spar, and in hot springs that of arragonite. Calc tuff is usually a porous mass, but sometimes its layers are sufficiently firm to be used in

building, and are then valuable from their lightness. The most remarkable example of such 'Travertin' formations is to be found in Italy, and so rapid is the progress of deposition, that at the Baths of San Filippo, a mass, 30 feet thick, has been formed in twenty years. These springs are made use of to procure stone casts, the lime being deposited in a firm and solid state on models immersed in the water. In Hungary, calcareous springs have created for themselves banks of calc tuff, the peaks of which project and look like craters. Such tuff is sometimes rendered still more friable and porous by enveloping moss and leaves, and in other instances, although soft when fresh broken, it becomes, on exposure, a hard building stone, as at Jena.

Chemical Deposits.

Silicious Tuff, or Sinter.—Thermal springs deposit, on cooling, much of their silex. The hot springs of Iceland, and especially the Geyser, are of this description. At intervals of a few minutes, a lofty column of hot water is thrown up, and then a dense fog overspreads the surrounding ground, and from this condensed and cooled spray the silex is deposited in the porous form of tuff, or sinter, whilst, in the interior of the basin, a species of opal is formed. Several springs which deposit silex are found in the Azores; and it is very probable that semi-opal and hyalite, which are found frequently in Germany in the crevices of basalt, and in short, most of the silicious minerals which are so abundant and so beautiful, in connection with that formation, have been formed in a similar manner by the filtering away or the absorption of the water by which the mineral matter had been originally dissolved.

Chemical Deposits.

Bog Iron (Limonite).—Ferruginous springs or waters deposit a brownish red scum of peroxide of iron on their banks, or when they pass through boggy or marshy districts, form what has been called from such localities bog or marsh iron. When the waters contain also much silica, it will likewise be deposited; and as sand or gravel may be also mixed up with and consolidated by the mineral matter, a variety of ironstone is formed, which has been called sand ore.

In Sweden, bog ironstone has been fished up from under the sea, where, according to Hausmann, it still continues to be produced, and it would be interesting to compare the microscopic structure of this ore with that produced in fresh water. The presence of phosphoric acid in bog iron ore, so unfavorable for smelting, is probably consequent on the decay of organic bodies in the water during its formation.

Chemical Deposits.

Deposition of Saline Bodies.—To the chemical class belong the saline deposits which are thrown down by some springs, streams, and lakes, and generally they are not very extensive. From the mineral springs of the Baths at Vienna, a fine powder is precipitated, which consists of gypsum and muriate of lime. In the South of Russia, several lakes annually overflow their banks and deposit a saline crust; but this phenomenon is much more common in the lakes, and especially in the very low grounds, of the warmer zones. In six small lakes near Terrareh in Egypt, soda has in this manner been deposited in large quantity. The extensive turf moors at Franzensbad, near Eger, are partly coated with a white saline crust of sulphate of soda (Glauber salt) and sulphate of iron, which is now turned to a profitable use. Some salts exude out of the rocks, especially in cavities, as is the case with saltpetre, nitrate of potash or nitre, in a remarkable degree in the limestone caverns of Brazil and of Ceylon.

Chemical Deposits.

Mineral Oil, or *Pitch*.—In several parts of the earth are found springs of a mineral oil, which on drying becomes either asphalte or a species of coaly mass. The Carpathians and the vicinity of the Dead Sea are rich in these springs, as is the island of Trinidad, where there is a complete sea of asphalte. In Germany, at Brunswick, several asphalte springs have more recently been discovered. Another locality is the island of Zante.

Organic Formations.

From the action of Plants or Animals—Turf.—This description of formation is rightly connected with geognosy, as it is in some instances covered by the more modern mineral deposits of little extent, and in others exhibits a passage into the brown coal, which is necessarily considered as a constituent part of the earth's crust. Turf consists principally of an accumulation of marsh and water plants, especially of various species of moss, the lower layers of which have in succession died, and through the action of humic acid been changed into a peculiar brown, felted, slimy, and combustible mass. In some of the layers of turf, the remains of plants are so decayed and changed that their original condition can only be inferred, but in others the actual species of the moss can yet be determined. In some bogs, the growth appears to have ceased, whilst in others vegetation is still vigorous on the upper surface. In Alt-Warmbrücher moor, near Hanover, which is being cut for the second time, the turf has been re-formed, according to Leonhard, in fifty years, and during the last thirty years a layer from 4 feet to 6 feet thick has been in course of formation. At Franzensbad, near Eger, a similar fact has been observed, the exhausted turf hollows having been again filled with new turf plants in from ten to twenty years, which are formed into useful turf in from fifty to one hundred years. The great bogs of Ireland are amongst the finest examples of this kind of formation, both as regards their extent and depth; and although no very detailed or satisfactory observations have been made on the new growth of bog in old exhausted hollows, where drainage and cultivation have not so modified the conditions as to stop it, a very slight observation is sufficient to shew that the first step of the accumulation of moss plants can yet be traced. Keferstein has remarked that turf formations are rare on calcareous and frequent on silicious bottoms, but Ireland is against the generality of this observation, as turf is abundant in some of the limestone districts, and has in several cases grown over lacustrine deposits of shell-marl. Thick beds of turf occur on the summits of some high hills in Ireland, and other countries, where a clay bottom retains the moisture. On the banks of the North Sea, a species of turf is formed from accumulations of sea weed. Large masses of bog have sometimes been detached, and become floating islands, one of which on the Gördauer Lake, in Prussia, was so large as to support a hundred head of cattle, until, in 1707, it was broken into three parts by a severe storm. Sometimes turf is found below the high-water level of the sea, as at Greifswalde and Geageland, on the East Sea, and as it appears in a very pretty example on the north coast of Ireland, near Portrush, the elytra of beetles (fresh and bright) occurring between the layers of turf. Turf is also formed in the warm zones, as at San Paulo in the Brazils. In the Irish bogs, the roots, trunks, and fragments of the branches of large trees, both oak and fir, are abundant, and in several instances, two or three successive sets of the roots are observable, standing upright one above the other. As before observed, turf exhibits a connecting link between the existing epoch and the next preceding it. It is thus very compact, full of iron pyrites, which frequently induces spontaneous combustion and the formation of sulphates, often contains fresh-water shells, and is covered by

layers of sand and clay, and exhibits therefore a passage to the brown coal, being more nearly connected with the diluvial than the alluvial section of the post-tertiaries. In Langensalza, a bed of such turf with stems of trees was found under a covering of 12 feet of sand and 7 feet of earth. At Wittgendorf also, near Sprottau, in Silesia, turf resting on fresh-water marl is covered with sand and gravel.

Organic Formations.

Submarine Forests.—On various parts of the coast of Great Britain and of the North of France, are found the remains of ancient growths of trees and plants in positions below the level of the sea, though they are of species still living. These become visible sometimes from the encroachment of the sea on the coast, and at other times simply by the ebb of the tide, and have thereby obtained their name. They probably owe their present position to a partial depression of the land. A very beautiful example of such remains of trees has been brought forward by Captain James, R. E., being a discovery made whilst excavating the splendid new steam basin in the Portsmouth Dockyard; but from the thickness of mud and gravel over this deposit, it may be doubted whether it did not rather belong to the preceding epoch than to the present. On the western coast of Jersey, Colonel Lewis has noted a fine example of such forests.

Organic Formations.

Coral Reefs and Islands.—They are found in the Pacific and Indian Oceans and in the Red and Mediterranean Seas. Formerly, the formation of ancient limestone hills was explained by reference to these reefs and islands, as it was supposed that great masses of rock could be raised from the bottom by the continued growth of polypes and the formation of their calcareous coverings,—and that such masses of coral rock covered the sea bottom; but recent researches, especially those of Quoy, Gaimard, and Ehrenberg, have shewn that the growth of coral does not continue in great depths, and that coral reefs or islands are only incrustations on the inequalities of the sea bottom, whether due to mountain masses as yet not elevated to view, or to banks of detritic matter, and are therefore not generally more than 20 feet or 30 feet thick. Whilst, then, such continuing formations explain the true coral reefs of ancient epochs, they cannot alone account for all the masses of limestone, though polypes may have participated in their formation. This more perfect knowledge of the habits of coralliferous zoophytes explains, however, more fully those deposits of shale with calcareous layers of corals which form so large a portion of the carboniferous system.

Organic Formations.

Infusoria.—Ehrenberg has discovered that whole masses of rock consist of little else than infusorial remains, as in tripoli, polishing slate, and kieselguhr. Sometimes the infusoria which have formed these strata belong to extinct and sometimes to still living species, so that even the microscope continues the train of reasoning as to successive creations which has been drawn from the contemplation of higher organisms. The silicious skeletons of these minute beings are specially accumulated at the bottoms of marshes and stagnant waters, as in the turf moor near Eger, where a large quantity of kieselguhr and thick beds of a white silicious powder have been formed, both consisting of the unmixed silicious portions of still existing infusoria. Many of these infusorial substances, such as tripoli, polishing slate, and kieselguhr, have been classed with metals from their general appearance, but their true character has now been made known by the microscope. Most of the infusorial deposits probably belong to the antecedent epochs, but that of Eger is evidently recent, and doubtless there are such in all those countries where the waters flow over much decomposing

silicious rock. It is unnecessary to enumerate the various animal remains which have been dug up in bogs, or found in alluvions; but the remains of man's works should be noticed. In Sweden, on digging the canal which joins the Mälar to the East Sea, the four walls of a fisherman's hut, with its fire-place and fragments of coal, were found under 50 feet of sand and mud, which is explained by Lyell as a depression of the land. The wooden bridge on the Dreuthe, in the Netherlands—the wooden bridge made by Germanicus in his German war—was found under a bog; and in Galway, as stated in the tabular view, a hut and paved passage were found under about 30 feet of bog, by the late Captain William Mudge, R. N.

CONNECTION AND EFFECTS OF IGNEOUS, AND SPECIALLY OF ERUPTIVE ROCKS, ON THE EARTH'S CRUST.

In the preceding pages, this branch of geological inquiry has been frequently referred to, and in the tabular views of rocks and of formations the connection of the igneous with the stratified has, as regards time, been pointed out. The present object is to trace briefly the results of that connection in modifying the earth's crust.

In its general appearance granite is the most distinct from recent lavas, and yet there are not wanting connecting links, afforded either by the physical phenomena exhibited by the granite, or by the intervention of rocks which form a sort of mineral passage between them—granite, syenite, greenstone, and basalt forming a chain which connects the ancient with the modern igneous rocks.

The great extension of the granite group over the surface of the globe indicates that it is due to some very general, and not to mere local causes; and in like manner the frequent co-existence of granite and metamorphic rocks indicates that both are related to such great modifying causes. In the Erzgebirge at Geier the granite has forced itself up, in three blunt hills, through the mica schist, which in its vicinity has been further changed into gneiss; and in the county of Cavan, in a similar manner, rounded hills of granite occur amidst an ancient metamorphic schist. In the former case the granite has evidently been protruded subsequent to the deposition, and even to the partial metamorphism of the schists, but the exact epoch of its protrusion is not determinable, nor is it limited even in the ascending scale. In the granite of the valley of the Neckar, near Heidelberg, however, though its antiquity cannot be settled, there is a limitation upwards, as it has been laid bare by the denudation of the new red sandstone which had once overlaid it; and such examples as these prove the repetition, at various epochs, of the action of elevating forces, by which the surface of the earth was disturbed and igneous rocks forced upwards. Confirmatory of these views, granite exhibits itself in two forms, one as constituting mountain masses, and the other as exhibiting itself in veins. The veins are of various thicknesses, from a few inches to several feet, and it frequently happens that massive granite is penetrated by veins of granite differing from it in constitution: thus Leonhard has called the one, principally porphyritic from the presence of disseminated felspathic crystals, mountain granite; and the other, which is not porphyritic, vein granite. Granite, by acquiring hornblende, sometimes passes into syenite, and distinct veins of granite are frequently observed traversing syenite. In the Odenwalder, the syenite is traversed by many granite veins, but a vein of the syenite in the granite has not as yet been observed, so that it has been assumed that the syenite is older than the granite. The frequent connection of granite with gneiss and mica schist brings it more in relation with the metamorphic processes, whilst the passage of syenite into greenstone keeps up a similar relation between the ancient and modern eruptive rocks. Another instance of such relations may be also cited in granulite or weisstein, where compact felspar becomes the principal constituent; for although

this rock sometimes assumes an independent massive form, and in veins traverses granite, it can only be considered a member of the group which includes the trachytes or felspathic lavas. The veins of granite, granulite, and syenite, often contain large fragments of gneiss and other schistose rocks, and the strata adjacent to these masses are both much contorted and greatly metamorphosed. At Meissen and Hohnstein in Saxony, the granite even overlies the quadersandstein, but it is supposed that this is owing to disturbance: at Christiania in Norway, and in the Harz, it is found between the layers of primary schist and limestone, into which it penetrated by veins, changing the schists into a species of hornstone; and such examples might be multiplied from many such districts.

Greenstone.—This rock, brought so closely into relation with the granite group by the intervention of syenite, approaches in like manner very near to the basaltic on the other hand, so that it affords a connecting link between them: but whilst granite and syenite exhibit only very obscure examples of intercalation or even superposition to stratified deposits, greenstone is often so closely connected with both the non-fossiliferous crystalline schists and the primary schists, not only occurring in intruded masses and penetrating veins but also in beds alternating with the regular strata, that it was by Werner classed with them. Where the schistose beds are penetrated by greenstone, the strata are often much contorted, and the structure becomes intricate, affording thus another analogy with decided igneous rocks; and where the two classes of rocks are disposed in regular and parallel strata, distinct transition from one to the other can frequently be observed: but this is not always the case, as in some instances, especially where a thick bed of limestone occurs, the separation between the two is very distinctly marked. It is thus that, reviewing the various circumstances connected with this rock, the more decided metamorphic theorists see in it an ultimate result of metamorphism, whilst the eruptive theorists connect it with erupted rocks, and even consider the alternating beds as the products of so many distinct eruptions. The more general aspect of this rock is characterized by knoll-like or conical masses, and these are sometimes recognized at a distance as small lump-like excrescences projecting above the stratified deposit. The columnar structure is rare, but it is occasionally observed. The close resemblance between syenite and greenstone makes it desirable to have some rules for distinguishing them. Those of Cotta are as below.

Syenite.	*Diorite or Grünstein.*
The dark green hornblende, blended with the yellowish or red Labrador felspar and weathering nearly together, both form on the surface an iron-shot crust.	The mostly white albite weathers sooner than the dark green hornblende, so that the crystals of the latter project above the weathered surface.
Colour.—Reddish or whitish green.	Green, approaching to black.
Occasional Ingredients.—Almost constantly small brown crystals of titanit, and sometimes quartz and mica.	Iron pyrites and magnetic pyrites (simple sulphuret of iron).
Fissures, lined with epidote.	Also common.
Forms.—Massive and angular, and constitute mountain masses.	Conical: knolls, masses, small masses, layers, or veins.

It may be mentioned that, as in granite, minerals and metals are sometimes extensively developed in this rock,—a remarkable example of which may be cited from the neighbourhood of Schwarzenberg, where it penetrates the mica schist, by layers more or less parallel to the stratification; though such arrangement is sometimes

so widely departed from, that, combining the divergence with the evidence of fragments of the adjacent rocks taken up by the greenstone, it has been suggested that the igneous matter has been forced into the fissures which have taken place in the natural lines of lamination of the strata. Some of these conformable dykes are more than 30 feet thick, and the ore is so abundant as even to conceal the original composition of the rock. The ores are especially magnetic pyrites, iron pyrites, arsenical pyrites, tin ore, black and brown blende, lead glance, and silver; and the minerals are garnets, vesuvian, chlorite, epidote, tourmalin, prase, mica, calcareous and brown spar, and many others. Granular limestone and dolomite occur in connection with this rock, as in other examples.

Serpentine is allied to greenstone, and exhibits similar physical features. Its veins penetrate the crystalline schists, as well as granitic rocks, and it appears to have been protruded amongst the beds of the Jura formation, being abundant in the Alps. The well-known mixture of serpentine veins in marble is a curious example of metamorphic action, as they indicate rather diffusion than penetration, and cannot be connected in many cases with any great mass. The fissures and cavities of serpentine are often covered with asbestus.

Porphyry Group, including felspar porphyry, pitchstone porphyry, and augite porphyry.—These rocks all affect a similar physical character, appearing in lump-like masses and projecting dykes into granite, crystalline schists, and various stratified deposits. They frequently appear as isolated hills amongst other rocks, and have been noticed in all parts of the earth. The felspar porphyry, including hornstone and claystone porphyry, forms extensive masses, and also dykes of great length, which frequently contain fragments of the rocks passed through, and are sometimes bounded by a breccia formed by their action upon them. The pervading form of this group of porphyries is rather angular than round, and tabular beds and columns are common, so that there is a close analogy in structure to basalts. Metallic veins are rare in the porphyry itself, though more frequent at its contact with schists. A remarkable example of these rocks is seen in the Tharander Walde, where several powerful dykes proceed tangentially rather than radiating, from a round knoll more than a mile in diameter. The main mass lies between gneiss and clay slate, and dykes from it ramify through both. At the 'Zeisigsteines' it becomes columnar, and at the Esberge still more so. The overlying rock is here the 'Quadersandstein,' which affords a curious analogy with the similar porphyry in the county of Antrim. Between Freiberg and Frauenstein, dykes many miles long cut through the gneiss, and are themselves penetrated by metallic veins. Pitchstone porphyry, including pitchstone and pearlstone, is comparatively rare, and is usually connected with other porphyries, which it either penetrates in mass or by dykes: it occurs in Saxony, in Hungary, and extensively in the island of Arran: it appears also in the felspar porphyry district of Antrim.

Melaphyr, (*augite poryhyry, augite rock, &c.*)—This rock is sometimes amygdaloidal, and generally appears either in small knoll-like masses or in irregular dykes, penetrating massive and schistose rocks, and effecting important changes in the fossiliferous deposits. The varieties of this rock are very numerous, as it becomes porphyritic from detached crystals of augite, of mica, or of felspar; but a negative character is obtained from the absence of quartz. Its bladder-like and amygdaloidal structure, and the occasional appearance of columns, approximate the rock to the basalts.

Basalt Group, including clinkstone and trachyte.—This remarkable group brings up the working of ancient igneous forces to the very threshold of the existing epoch. In basaltic countries, isolated conical hills are common; such independent knob-like masses of all sizes from 5 to 1000 feet in height, and from 10 to many thousands in

diameter, projecting above the surface of the country, and sometimes being connected together in one great mass. The basalt is sometimes like a stream of lava spread over other strata, and it is frequently found alternating with them: it has penetrated through all the ancient igneous rocks and through all the fossiliferous strata up to the post-tertiary, and some of its varieties often intersect others, though generally in such cases the basalt is older than the clinkstone or trachyte. Where basaltic dykes have crossed other rocks, remarkable chemical and mechanical effects have been produced; granite gneiss and mica schist have been reddened, and (especially the mica) partially melted; clay slate, burnt and hardened; sandstone, reddened, glazed, and reduced to a columnar structure; stone and wood coal, charred; limestone, sometimes deprived of its carbonic acid, and frequently reduced from an earthy or compact to a crystalline state; shale, changed to jasper; fragments of underlying beds, raised to a higher level, and the regular strata disturbed and uplifted, though not to the same degree as by granite and porphyry, the chemical exceeding the mechanical effects on this class of rock. It is in basalts that the columnar structure becomes most striking, and wherever a deep section can be observed, as on the northern coast of Ireland, highly columnar beds will be seen associated with others purely massive, and the several beds separated the one from the other by beds of ochre and of amygdaloid. The columns are of various forms, the pentagonal and hexagonal prevailing; and they are often, as at the Giant's Causeway, beautifully jointed: they appear sometimes on the face of a bed, like long rows of closely arranged pillars; at others they radiate from a central axis, and in dykes they are frequently horizontal. The bladder or bubble-like cavities of basalt, and specially of amygdaloid, have been filled with a great number of beautiful minerals, including the whole family of zeolites. The magnitude and beauty of basaltic dykes are frequently brought to more marked observation by the striking contrast between the nearly black colour and the mason-like aspect of the dyke and the lighter hue of the stratified rocks through which they pass, or by their independent appearance, projecting like walls above the surface when the softer strata have been worn away.

Phonolith (clinkstone and clinkstone porphyry) and trachyte are not so widely spread as true basalts. Passages between clinkstone and trachyte may be traced, and, where they occur in masses, the larger are generally more of trachytic, and the smaller of phonolitic character. The place of phonolite is the basaltic districts, and, as well as trachyte, it is closely related in nature to that rock. The columnar and tabular forms of structure are observable, and they form dome-shaped or conical hills. Trachytes, occasionally varying to phonolite, occur in the well-known Siebengebirge, in Hungary, in the South of France, and extensively as Andesite in the Andes. As true lavas assume the basaltic and trachytic forms, it may reasonably be assumed that, excepting in the exhibition of craters, basalts and trachyte are strictly analogous to such lavas, and therefore bring the igneous rocks up to the existing epoch.

VOLCANIC GROUP.

Volcanic products are found in every region of the earth's surface, some of which have proceeded from volcanoes now extinct, and the rest from those still in action; and so closely are these products related to those of the basaltic and trachytic group, to which they are sometimes also placed in near proximity, that it would be scarcely possible to distinguish them, were it not that in the ancient groups craters are wanting, as also those substances which have been thrown up from them by eruptive force, such as ashes, lapilli, &c. This indicates a remarkable difference of circumstances; and as the evidence of geological formations has proved that numerous oscillations must have taken place, the dry land of one epoch having been submerged, and when

covered as a sea bottom by new deposits again elevated to the surface, the absence of craters cannot be accounted for by supposing that no sub-aerial eruptions took place in these remote epochs, but rather by supposing that the craters were in part obliterated and filled up when submerged, and in part are yet hidden under the sea; whilst, on the other hand, it may be assumed that sub-aqueous eruptions are in like manner now proceeding, which will be made manifest hereafter when elevation has brought up the present sea bottom, and exhibited its basaltic and trachytic non-crateriferous rocks. Modern observers have indeed thought that they could trace erupted products, like those of sub-aerial volcanoes, amongst the ancient strata; but such proof of the existence of volcanoes it is evident is not indispensably necessary. Volcanic products are divisible into lavas, erupted substances projected from the crater into the air, and muddy matter. Lava is of various descriptions, such as basaltic, greenstone-like, trachytic, porphyritic, leucitic and slag-like. The erupted substances are loose fragments of slag, obsidian and pumice, volcanic *bombs*, so called from their resemblance to *shells*, which are sometimes hollow and sometimes have a solid lava kernel within a coating of slag,—smaller pieces of slag called lapilli, and volcanic sand and ashes. The muddy products are trass, tufa, peperino, moja, which are not present in all volcanoes. These substances are of great practical value in the preparation of hydraulic mortar.

The most remarkable extinct volcanoes are those of the Eifel in Germany, and of the Vivarais and Auvergne in France, in which districts numerous craters and lava streams can be accurately traced, as well as the other products of sub-aerial eruptions.

It is unnecessary to enumerate here still active volcanoes, but it is desirable to notice their geological effects, and in order to comprehend them, to bear in mind that earthquakes n the existing epoch are a portion of their phenomena,—the earthquake often preceding the volcanic eruption,—being the result of unusual movements in the interior of the earth which is connected with its surface by the volcano. It is thus that whilst the streams of lava which flow over the sides, and the dykes which penetrate the walls of the crater, illustrate the more ancient igneous products, the movement of the earth's crust, its upheaval or its depression, and the cracks which fissure it under the action of the earthquake, are equally illustrative of the mechanical effects of former forces of a similar nature. Von Buch has divided volcanoes into central and linear,—the one in which a great central volcano is surrounded by a number of smaller, as in the case of Etna and the Lipari Islands, the other in which they are arranged in a line, as if related to some great crack, as in the Andes, in the Grecian Islands, &c.; and a careful examination of the earth's surface will doubtless shew that the modifications of the forms of mountain chains may often be explained by similar variations in the mode of action of ancient igneous rocks, when forced upwards.

In the great earthquake of Chili, 19th November, 1822, the shock was felt along the coast for 240 miles, and by many natural appearances, such as the exposure of beds of shells, and of an old wreck, at times of the tide when they were not before so exposed, it was ascertained that at Valparaiso the uplifting amounted to three, and at Quintero to four feet; and when it is considered that the great chain or axis of disturbance along which the volcanoes are arranged is at a considerable distance, it may be surely assumed that the intervening country had been raised in a much greater degree. There are also traces of more ancient shocks by which the coast had together been raised about 50 feet. The rocks of the coast are granite and syenite, in which there are numerous parallel cracks which can be followed landward for 1½ mile. The effects of this earthquake could be traced over a space of 100,000 square miles.

An earthquake shook violently part of Wallachia on the 11th January, 1838, and was very instructive, as many parallel fissures were formed, and then filled by matter forced upwards.

The earthquake which destroyed Lisbon, 1st November, 1755, was felt in all Europe, so far as Norway, on the north coast of Africa, in several of the West India Islands, and by many ships at sea. At Lisbon, an adjacent hill was split in two, and the new quay sunk 600 feet below the water. The changes of level of the celebrated Temple of Puzzuoli, near Naples—the rising and sinking of the land in Scandinavia—the appearance of islands forced up—are all phenomena which exhibit the still continuing action of elevating forces. Jorullo, in Mexico, affords an example of volcanic action combined with extensive elevation, and Skaptaar Jokul, in Iceland, one of a stream of lava which may vie with many of the ancient basaltic streams—being about 50 miles long, 12 miles wide, and on an average 100 feet thick. The contemplation of such wonderful effects of causes still acting, may well prepare us to estimate those of forces which acted according to the same laws in former epochs. Whilst, therefore, the action of water has been generally to wear down, transport, and re-deposit in nearly regular and horizontal order, or, in other words, to restore the level of the earth's surface, the action of heat has, in conjunction with electricity, &c., tended to disturb that level, and to raise some portions of the surface above others. Such an elevation could not be effected without much disturbance and the formation of cracks, and the general result would admit of much modification. Where, for example, the elevating force acted on a point or small space, an isolated mass or mountain might be formed, and the cracks would radiate from a centre; or should the superficial pressure be diminished, the crust might be raised like a great bubble, and, finally separating at its apex, form the circular wall of what Von Buch calls a crater of elevation: if acting on the line of a crack, either one side might be uplifted, and thus form a steep precipice overhanging a plain,—an appearance not unusual in nature,—or both sides may be uplifted, so as to form two precipices, with a valley of elevation between them; and again, if cracks are formed transverse to others, and upheaving takes place, there will be various modifications of the primary ridges. These forces continuing to act at intervals for ages, have produced the great and the cross chains of mountains. Von Buch, pursuing these inquiries, observed that in certain districts the mountain chains, the strike of the strata with some modifications, and even the great valleys, had certain predominant directions; and Elie de Beaumont, extending Von Buch's researches, founded upon them, in 1830, his Theory of Elevation, according to which *all mountain chains of the same age have also the same direction.* He assumed that the earth's crust has been elevated into mountains at various periods by forces acting at all places in parallel directions; and to determine the relative ages of such upheavals, appeals to the undisputed fact, that uplifted and highly inclined strata must have been in existence prior to the upheaval, and horizontally deposited strata overlying the inclined must have been formed subsequently to such upheaval; so that it became evident that mountain chains had been formed at very different times, and that the epoch of their elevation must have exercised much influence on the direction and grouping of sedimentary deposits. M. Elie de Beaumont has in this manner distinguished about fifteen systems of elevation, according to their age and direction, of which the most remarkable are the twelve following.

1. *System of Westmoreland and Hundsrück.*—Direction of elevation, N. E. ¼ E. and S. W. ¼ W. No newer strata than the Silurian, and probably a part of Devonian, uplifted. This includes the Eifel, the Taunus, the Isle of Man, and South Shetland. 2. *System of part of the Vosges.*—Direction, E. 15° S., W. 15° N. Mountain

limestone, but not the coal-bearing strata, uplifted. To this belong the hills of Bocage, in Calvados. 3. *System of the North of England.*—Direction, S.—N. The coal-bearing strata are the most recent affected in this elevation. 4. *System of the Netherlands and of South Wales.*—Direction, N. E.—S. W. The whole of the coal formation affected. 5. *System of the Rhine.*—Direction, S.—N. or S. S. W.—N. N. E. Strata to the Zechstein (magnesian limestone) uplifted. The Vosges, Schwarswald. 6. *System of Bohemian and Thuringian Forests.*—Direction, S. E.—N. W. The keuper is the newest formation disturbed. La Vendée, Bretagne. 7. *System of the Erzgebirges.*—Direction, S. W.—N. E. The Oolite or Jura, but not the Quadersandstein, affected. Côte d'Or, Mount Pilas and the Jura in part. 8. *System of Monte Viso.*—Direction, N. N. W.—S. S. E. The older but not the newer chalk affected. 9. *System of the Pyrenees and Apennines.*—Direction, N. W.—S. E. The younger or upper chalk, but not the tertiary strata, affected. This system being parallel to No. 6, it is often difficult to separate one from the other. Harz, Teutoburger Forest, &c. 10. *System of Corsica and Sardinia.*—Direction, S.—N. The lower tertiaries, but not the upper, affected. The basalt of Hesse. 11. *System of the Western Alps.*—Direction, N. 26° E.—S. 26° W. The newer tertiaries affected. 12. *System of the main chain of the Alps, from Wales to Austria.*—Direction, W.—E. or E. N. E.—W. S. W. A portion of the post-tertiaries affected. Monte Ventoux, Leberon.

Such is the theory as originally propounded by De Beaumont, and it brings down the evidence of successive elevations almost to the existing epoch, but against its strict application there are many objections. Many mountains have evidently not been raised by one impulse, but by many acting at different times and frequently in the same direction; and as the crust once broken becomes easily fractured in the same line, igneous rocks of different ages may often be traced along a line common to several successive elevations; nor can the assumption that the elevations of any one epoch have every where been effected in parallel and straight lines be admitted. To follow out such lines of elevation over the earth's surface, would indeed be most difficult, more especially, as the more frequently repeated they were found to be, the more approximated in direction they would become,—a difficulty even perceptible in the twelve great systems enumerated; but even rejecting the generalization, it must be acknowledged that the groundwork of the theory is correct, and that its promulgation has had a most powerful effect on the progress of geological science.

As in the formative processes resulting in the deposition of the mineral strata of the earth's surface at various epochs, and the entombment of the relics of successive races of organic beings, so also in the forces operating to disturb the tranquillity of the universe, and to render the surface of the earth uneven, or a mixture of hill, valley, and plain, the course of nature has now been traced from the remotest to the still passing epoch, and every where, and in all times, the same great causes have been seen to act in breaking up or in re-forming the mineral crust. But it may be still doubted how the great elevating force has been developed; and here indeed a difficulty must be felt in replying, as direct observation can only extend to a mere film of that earth, the surface of which it has affected in so striking a manner. The facts of disturbance are palpable, and the nature of the forces producing them can be inferred by reasoning, though not demonstrated by observation. Electricity may be fairly classed with such forces, and yet it may be only a secondary cause; but assuredly ample reason has been adduced for the assumption that heat must at least be a primary one. This subject has been learnedly discussed by Gustav Bischoff in 1837, and assuming the fluid condition of the central portions of the earth from heat, he demonstrates from physical considerations, that hot springs, the production of massive

rocks from the cooling of the fluid mineral matter, volcanic eruptions and earthquakes from the expansive force of steam produced by contact of water with the still heated and fluid internal mass, are all natural consequences of such a condition. When then we look at the earth's surface, we see in it a whole, built up by slow degrees; and it has been the object of geological science to trace its growth through every step of its progress, and to separate the great compound into all its elements, both organic and inorganic.

PRACTICAL APPLICATIONS OF GEOLOGICAL SCIENCE.

In the preceding Sections, frequent reference has been made to practical results, and it has been shewn that a correct determination, on theoretic considerations, of the geological position of rocks, is generally most essential as a guide in practical research. The economic uses and value of many of these rocks have been pointed out; but it is also desirable to bring forward more distinctly the economic importance of the modifications of the surface, produced either by disturbance and elevation, or by denudation.

It must at once strike the Engineer, that the proper direction of roads, railways, and canals, though determined proximatively by an actual survey of the existing conditions of the earth's surface, has in fact been established by the geological modifications of that surface; and it must therefore be evident, that in entering on the examination of any country for such purposes, a valuable clue to the direction of the lines will be obtained by a knowledge of the prevailing strikes of stratification and of cleavage. And further, it is evident that a knowledge of the dip and arrangement of the strata must be of equal importance in determining the probable nature of the substrata, and therefore in guiding the Engineer as to his lateral deviation, either to avoid solid substances in his deep cuttings, or to arrive at them for his foundations. These aids are important, but the effect of modifications of the surface on the distribution of water is still more striking, and will be here noticed under a distinct head.

THEORY OF SPRINGS.

Water, perhaps the most important substance in nature, is in a constant state of change and movement, by which its purity and consequent fitness for performing the various functions to which it is destined are preserved. In the ocean, that great ultimate recipient of the larger proportions of the rivers and streams which flow over the earth's surface, the great difference of temperature between the Poles and the Equator causes a continued interchange of the cold and warm streams, the cold flowing below, from the Pole to the Equator, and the warm above, from the Equator to the Pole; and in like manner there is a perpetual movement upwards from the surface of the sea by evaporation, and downwards again by the flow of the water, which, having been condensed, falls as rain or snow on the earth, and returns gradually to the great reservoir from which it had proceeded. Simple as the processes are, the result is most important to mankind, as a constant and sufficient supply of this vital fluid in its pure and efficient condition is thus brought every where within the reach of organic action, either as springs, as rivers, or as lakes: and when this remarkable circulation is contemplated, we can scarcely wonder at the speculations of Keferstein, who saw in the world itself a living organism. Nor is it only in the mode of general supply, but also in the system of the distribution of water, that the wants of organic beings are consulted: for example, had the surface of the earth continued uniform and unbroken, the rain must have fallen more generally, and instead of being collected into separate channels, have soaked into and saturated the

upper strata, inducing a swampy condition of the surface, not probably very dissimilar to that it actually possessed, over large tracts, in the earlier geological epochs. Now on the contrary, the conjoint actions of elevating and denuding actions have produced chains of mountains, valleys, basins, and all the minor modifications of these three great forms. In the vicinity of mountains, it is easy to study the effect of this arrangement, as a river may be seen one day with its riband-like stream struggling along through a wide bed of stones and gravel, and the next, rushing forward an overflowing and turbulent stream, being swollen by the sudden rains which have fallen within the area of its leading or connected valleys, and been thereby collected into one great liquid mass. It will be readily understood by this statement that the more numerous the feeders, and the more closely connected with mountain masses on the summits of which a very large portion of moisture is always deposited over a comparatively small space, the more sudden will be the rises of the discharging or recipient river; and an Engineer must therefore always provide for such a contingency in constructing his bridges in a locality of this description. A large portion of water is thus carried off directly by running over the surface, but another large portion percolates through the surface to a greater or less depth, in proportion to its porosity. In clayey soils, this passage of the water is very slow, and the surface therefore in wet weather becomes moist and clammy, and in dry forms a crust fissured by cracks. In sandy or gravelly soils, the passage is very quick, and the surface keeps comparatively dry; but if the soil be not very deep, and the water be received on a more retentive substratum, the readiness with which the moisture is restored by a continued evaporation prevents an injurious aridity, and in consequence this condition of the surface is more generally favorable for vegetation than an impervious soil. If the sand or gravel be on the contrary very deep, and rests on an inclined surface, it acts as a filter, and whilst the water is entirely and rapidly removed, a general aridity of surface is produced. These considerations naturally lead to a perception of the true theory of Springs, which will now be further illustrated in detail.

1. It has been seen, that whilst part of the rain falls on the surface and runs off as on an inclined plane, another part filters through it; and this latter part, where collected together in any cavity of the less pervious substratum, forms a reservoir of water. Even on the sides of mountains, especially in damp climates, this process is constantly exhibited; and whilst the general surface becomes wet and boggy, numerous springs are seen wherever an inequality has led to an accumulation of water; and these, issuing as scarcely perceptible rills, go on gradually increasing as they join with others, and finally emerge in the greater valley as considerable streams. Such is the most simple and ordinary form of springs, from which, taking into consideration the peculiar modification in each case of the earth's surface, may be derived every other; and it becomes at once evident that springs will become superficial, small, numerous, but very temporary, where the pervious stratum is very shallow, and the inequalities of the substratum slight.

2. In addition to the water which forms the superficial springs on a mountain side, a portion may pass between the underlying rock and the superficial matter above it, whether the latter be a stratified deposit or ordinary detritus resulting from the simple decomposition of the rock itself; or should the overlying deposit be moderately porous, some of the water may pass directly through it to the underlying rock, and in either of these cases reservoirs of water will be formed in any great depression of that rock. This is a case which may be expected to occur in granitic and highly metamorphic rocks; and in the former, in which open fissures are rare, whilst superficial disintegration, especially in hot countries, has proceeded to a great extent, it affords

the only chance of meeting with deep-seated springs. Major Baddely, R. E., has shewn its application in Ceylon; and in two essays on the subject in the 'Colombo Observer,' has explained the principles which there regulate the appearance of springs. The underlying rock is a highly metamorphic hornblendic or syenitic gneiss, the outcropping edges of which have undergone much original modification, and is therefore supposed to form an undulated surface—thus, in fig. 10.

Fig. 10.

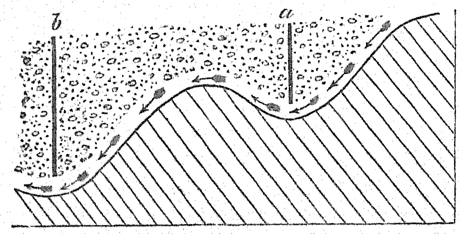
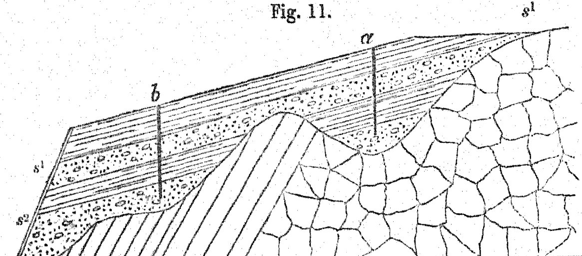


Fig. 11.

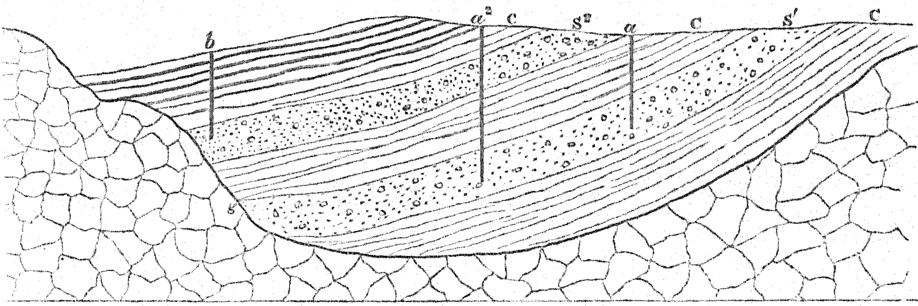


the hollows being filled up by a detritus, proceeding, according to Major Baddely, from the simple disintegration in situ of the more felspathic surface. From the mere inspection of the figure, it is evident that whatever may be the origin of the matter filling up the inequalities of the underlying rock, the water, either in part percolating through it, or passing between it and the surface of the sound rock, must accumulate in the hollows, and that in consequence it may be necessary to sink at *b* to 80 feet for water, although at *a* it had been found at 40; and further, that should the rock under *b* slope gradually off and become exposed in a valley or on the side of a hill, the water may all be carried off as quickly as supplied, and produce therefore no permanent spring,—circumstances which render the search for water in such cases very precarious. It may be further added in respect to this example, that a rising or projecting spring can only be expected where the water passing between the detritus and the rock is pent up by them, and thus affords a head of water; as if it merely filters through, the pressure can only raise the spring to the height at which the water stands at the time in the reservoir or hollow. The other form of this case is, where the hollows of the crystalline rock are filled by stratified deposits (No. 11) of shale and sand. Here, as the shale has been worn away, and the rock denuded at the summit, the water may gain access to the layer of sand (s^1), and produce therefore a spring under the bore-hole (*a*), the water being held back by the projection of the rock to the left of it. Where the water has saturated the whole of this stratum, it will rise over the projecting rock; but as the stratum is open to the valley below, it will be rapidly discharged, and produce no permanent spring under the bore-hole (*b*). Again, under both *a* and *b*, there will be a second supply of water due to the sand stratum (s^2); but as these lower reservoirs, from their imperfect connection with the surface,

must require a considerable time to fill, their practical value will be in proportion to their actual magnitude, or to the quantity of water previously stored by nature in them.

3. In the preceding instances, the accumulation of water has been considered to arise principally from that which flows over the underlying solid rock, but it may be also entirely due to that which enters directly from the stratified deposits, and is merely held back or dammed up by that rock, as in No. 12.

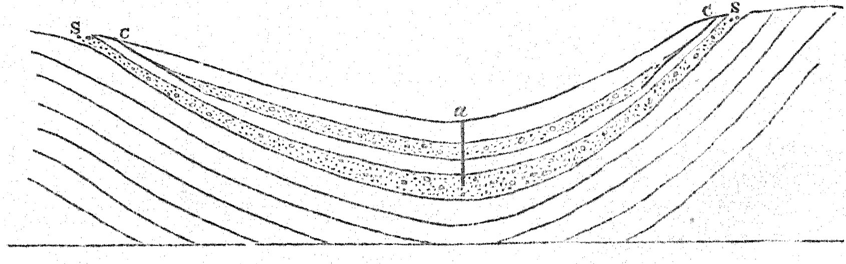
Fig. 12.



Here it is evident that the supply of water will be in proportion to the extent of surface on which the rain falls, and from which it is directed to the layers of sand (s^1 and s^2), the remaining mass being either clay or some other impervious stratum. If the supply be abundant, the stratum will be kept saturated up to the line of the bore-hole (a), and a constant spring be obtained; but if it be only small and casual, there may be a spring during the rainy season, or whilst the water is making its way through the stratum, but none at a later period, and the chance of permanency will be increased as the bore-hole is carried nearer to the rocky dam at g; and the same reasoning will apply to the upper stratum of sand (s^2), and its bore-hole (b): and it may be observed also, that a bore-hole (a^2), which could only find a temporary spring in s^2, by being carried through the intervening clays, might obtain a permanent one in s^1.

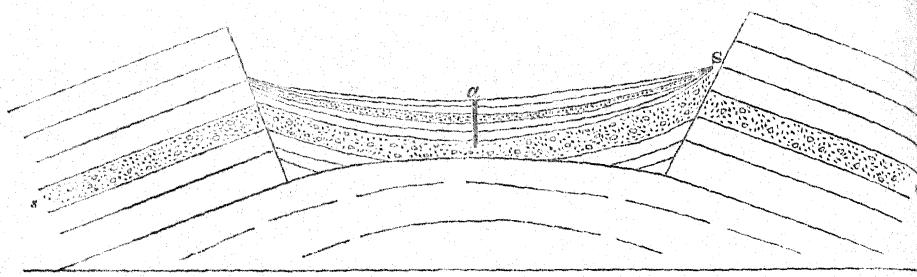
This case leads to those where the water is received and thrown up entirely by stratified deposits arranged in the form of basins or troughs; and this may happen either where the basin is produced by an undulation or depression of the underlying strata, or where it occupies the valley produced by the disruption of these strata by elevation; and as some precaution is necessary in reference to this distinction, each case will be considered separately.

Fig. 13.



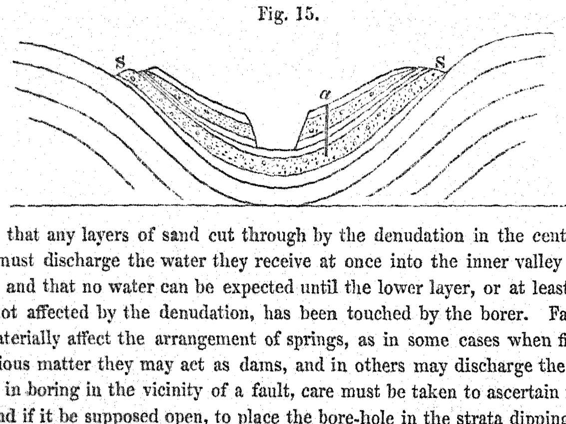
No. 13 is the first case where the strata of sand and clay have been deposited in a basin of undulation, and the water entering the sand stratum (*s*) is prevented from descending by the impervious strata below, and from ascending by the clay above; so that it is pent up in the sand stratum itself. An inspection of the figure is sufficient to shew that the nearer the bore-hole is made to the lower point of the valley, the more abundant and secure will be the supply, and the higher the jet from the aperture. If, instead of one layer of sand or gravel, there had been several, the reasoning would be the same, only it might happen that the upper layers had been closed up by the clay passing over them, as in the figure, and therefore be found unproductive of water.

Fig. 14.



No. 14 is a basin formed within a valley of disruption or even of denudation, or which differs from the preceding only in this circumstance, that the boundary walls, as it were, of the valley may in themselves be partly pervious, and therefore allow the water to escape. If such occur, the water cannot rise above the level of these discharging strata, represented in the figure. And again, secondary denudation may modify the basin deposit, and affect its supply of water, as in No. 15, where it is

Fig. 15.



evident that any layers of sand cut through by the denudation in the centre of the basin, must discharge the water they receive at once into the inner valley of denudation, and that no water can be expected until the lower layer, or at least the first layer not affected by the denudation, has been touched by the borer. Faults may also materially affect the arrangement of springs, as in some cases when filled with impervious matter they may act as dams, and in others may discharge the water,—so that in boring in the vicinity of a fault, care must be taken to ascertain its condition, and if it be supposed open, to place the bore-hole in the strata dipping *from it*.

It is conceived that these examples are sufficient to guide the Engineer in the application of principles to practice in every case, and he will at once see the great necessity of studying the geological as well as the physical character of the country in which he seeks for water. In granite, and in most crystalline rocks, such a search must be very precarious, as water can only be expected to occur in fissures. In stratified deposits, not metamorphosed, the occurrence of porous alternately with im-

pervious beds brings the principle into operation; and in proportion as the porous beds are looser in texture, as in the tertiary and post-tertiary sands and gravel, and the arrangement of them is more limited by a basin-like form, so will the chance of success increase until it becomes a certainty. A correct knowledge of the stratification at the outcropping of the strata must therefore become a sure guide to the Engineer, and in his boring he will carefully compare the strata passed through with such manifestations of them on the surface, in order to judge whether he has arrived at or passed through any one of them. Should he not be able to find any of these basin-like deposits of looser materials, his pursuit of water in more solid strata must be equally guided by a knowledge of these geological and physical peculiarities; such, for example, as in the chalk and even in the oolite districts, as in such cases the numerous fissures may permit the water to descend, until it is stopped by either a less fractured bed or by some of the divisional clayey beds of such formations; and when once such bed or stratum has been discovered in any district, it becomes an index for the operations of the borer.

Although the several methods of boring cannot be here described in detail, it may be well briefly to notice the most remarkable.—1. The common one, in which an auger is used for soft soils, and chisels or jumpers for rocks. In this mode the boring tool is connected with the surface by jointed rods, fastened firmly together, and which must be frequently raised to clear the hole of the débris; so that in great depths the weight to be raised and the time lost in separating and refixing the joints become sources of great expense.—2. The Chinese mode, by percussion alone; the borer itself weighing about 180 lbs., and, being suspended by a cord, is alternately raised and allowed to fall, the débris either passing up through grooves in the sides of the tool and being then drawn up when accumulated on the head, or received into a separate cylinder with a valve opening from below upwards. This method is much more economical than the common, and has been used very extensively in Germany, though it is subject to two accidents requiring great precaution,—viz. the great difficulty of drawing up a broken borer, and the danger, from the flexibility of the cord, of the bore-hole taking an oblique direction, and therefore requiring to be abandoned.—3. The system of Fauvelle, in which a hollow borer, whether it be an auger or a jumper, is used, the cutting tool being of larger diameter than the hollow stem, so that an annular space is formed around the borer; and water being either forced down this space, by a force-pump, ascends by the tube, bringing with it all the débris; or, if forced down the tube, ascends in a similar manner by the annulus. This arrangement renders it unnecessary to bring up to the surface the boring tools, as they are constantly kept clear, and a vast saving of time and expense is the result. (See Plate VII. for the Tools of each system.)

Connected closely with the subject of boring is its application in the search for economic minerals, and enough has been said in the preceding pages to shew the Engineer that there is a great difference in the positions of such substances, some being found, like coal, and salt, and ironstone, arranged in distinctly stratified beds; and others, like many of the metals, in veins. The forms of mining suited to each of these circumstances are different; and though they may be understood in part by an examination of the figures in Plates V. VI. and VII., it will be desirable to explain them more fully under the head of 'Mining—Mineral;' and this arrangement is adopted, as it will be possible, in carrying it into effect, to point out many useful adaptations of the great principles of mining to the art of Military Mining.—(See therefore 'Mining—Mineral.') For a general Table of building stones, in addition to what has been said in the progress of this Article, see 'Stones—Building.' And though the Plates of Fossils will be here given, to render every part of the Article available

in practice, a more complete view of the theory of the distribution of Fossils will be be given under 'Palæontology,' which therefore see.

I think it right, however, to state here, in reference to the Wealden, page 151, that the opinion formerly entertained by Cuvier, Dr. Mantell, and Professor Owen, was, that in Great Britain birds first appeared in that formation; but the latter most profound anatomist has since shewn that the bones then believed to belong to wading birds are probably bones of a Pterodactyle, and that the first tolerably recognized bones of birds in England are therefore those of the long-winged bird of the chalk Cimoliornis Diomedius (Owen), though even this determination may be as yet considered obscure. I may add also that the Rev. W. B. Clarke has come to a very different conclusion from Mr. McCoy as to the age of the Australian coal, considering it 'in part more ancient than that of Europe,' (Journal of Geographical Society, Feb. 1848): nor should I omit to mention that the *first satisfactory* determination of a quadrumanous fossil in the tertiary formation was due to Lieutenants Baker and Durand, of the Bengal Army, in 1836.

In closing, therefore, this section of the Article 'Geognosy and Geology,' I trust I may be allowed to append to it a few words in a personal sense. The Editors of the work having desired not to omit the subject, requested me to undertake it; and I have done so in respondence to their anxious wishes to render the 'Aide-Mémoire' complete, though with a full sense of the difficulty of doing in so short a time full justice to it. I do not expect that my brother Officers will at present find the article perfect, but I do hope that they will be induced by its perusal to pursue a study so useful as Geology must be considered by all practical men; and if they do so, and are thereby led to examine the geological structure of the country and collect specimens at their various stations, I shall be happy to assist them in their researches during my continuance in England, by examining any specimens they may send home, and correcting, if necessary, their descriptions of them; and I would in this respect particularly direct their attention to Fossils and to the material of superficial drift. In such matters as this there ought to be a feeling of co-operation amongst us, a desire to advance the character of our profession, rather than that of the individual; and I can conceive no case in which it can be better displayed than in geological research. When, indeed, I reflect on the manifest practical value of the science, I am surprised that its cultivation has not been more encouraged amongst us, and equally so that only a very small number have, notwithstanding this primary difficulty, studied it. I hope, however, this partial neglect of our science will pass away, and that ere long, at all our stations, there will be found observers amongst ourselves ready to elucidate the natural history, and discover the economic value, as well as to describe the military capabilities, of the countries in which they serve.

J. E. P.

GRENADE, FRENCH,*—is only now cast for the hand; and 12-pounder, 24-pounder, and 32-pounder Shells serve for the defence of Ramparts.

The large interior space is 3 *pouces*, 6 *lignes*, 6 *points*, in diameter; and the small one, 3 *pouces*, 5 *lignes*, 6 *points*, French measure.

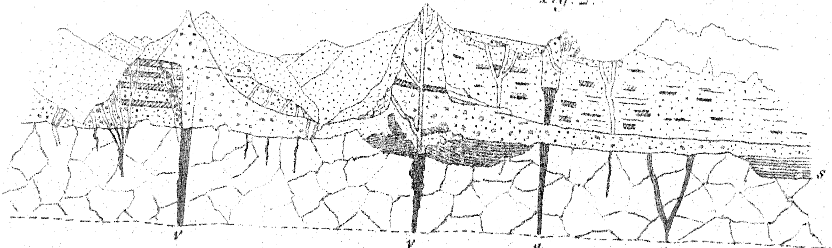
We must bear in mind that this grenade, whose dimensions are given in the Tables, is of rather a heavy calibre to be thrown with the hand, and that for this object it would be better to have them of only 3 inches, of the calibre of 4, weighing 2 lbs.

Grenades for ramparts weigh from 16 to 18 lbs., and their calibre is very varied.

* From 'Aide-Mémoire d'Artillerie.'

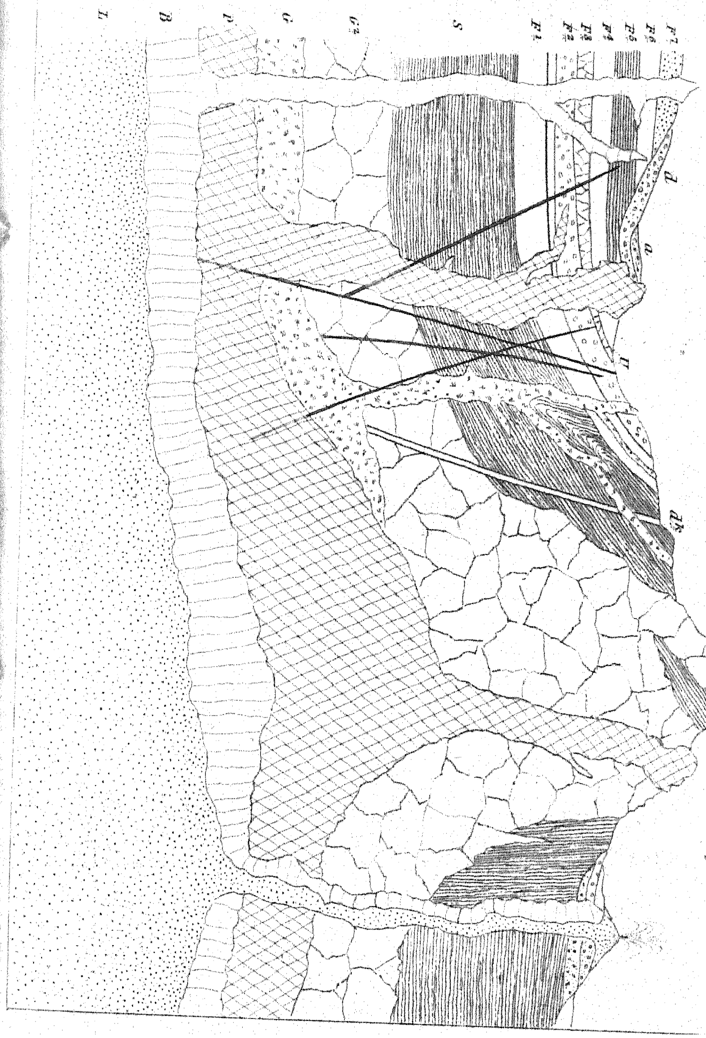
THEORETIC SECTION OF THE CANTAL EXPLAINING THE ERUPTIONS OF ITS EXTINCT VOLCANOES

Fig. 2.



v. Volcanic Chimnies.

s. Stratified tertiary deposits resting on Granite.



THEORETIC SECTION OF THE EARTHS CRUST FROM COTTA

L. Lavas Ancient and Modern. *F2 Devonian and Carboniferous.* *a. Alluvium*
B. Basalt. *F3 Magnesian Limestone.* *U. Mineral veins*
P. Porphyry. *F4 Trias or New Red.* *d2 Dyke*
G. Greenstone. *F5 Jura including Lias.*
G2 Granite. *F6 Cretaceous.*
S. Crystalline Schists. *F7 Tertiary.*
F1 Cambrian and Silurian. *d. Diluvium or Drift.*

Fig. 1.

Fig. 3.

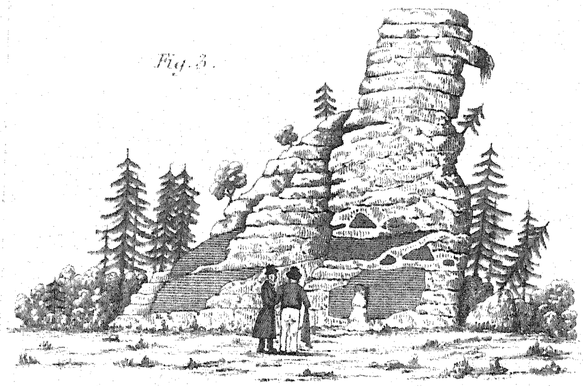


Fig. 4.

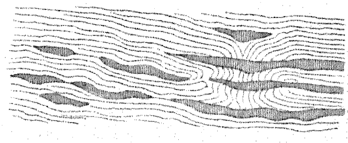


Fig. 5.

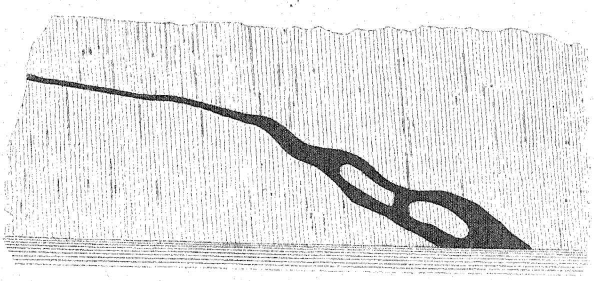


Fig. 10.

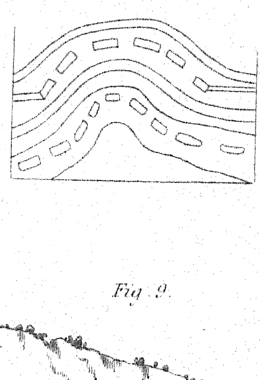


Fig. 6.

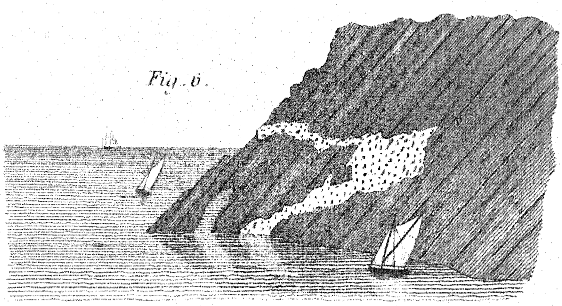


Fig. 9.

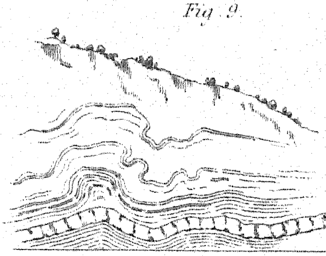


Fig. 7.

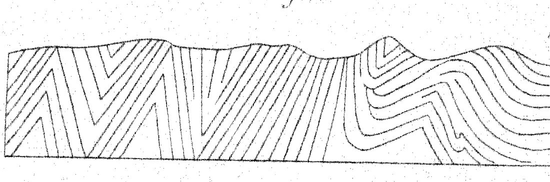


Fig. 8.

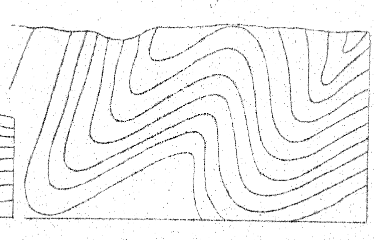


Fig. 11.

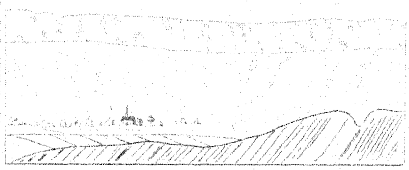


Fig. 12.

Fig. 13.

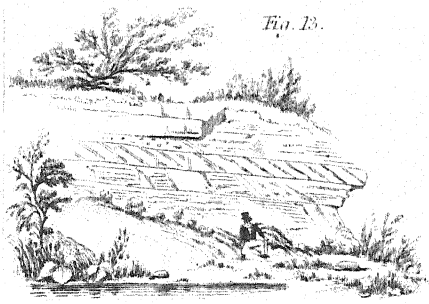


Fig. 14.

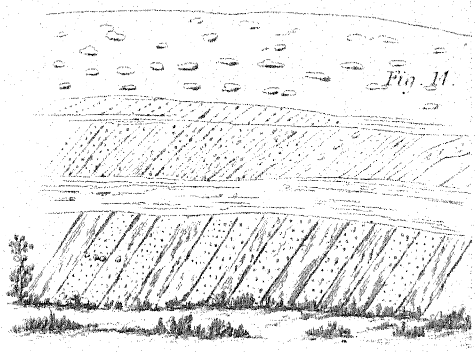


Fig. 15.

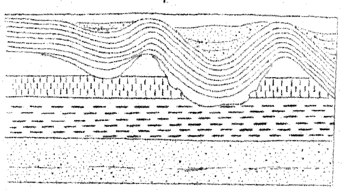


Fig. 17.

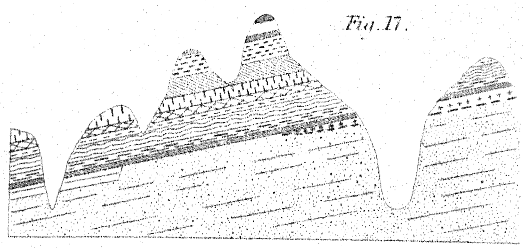


Fig. 16.

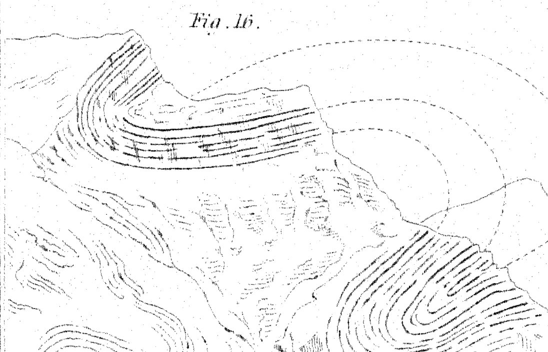


Fig. 18.

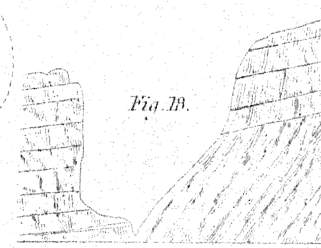


Fig. 19.

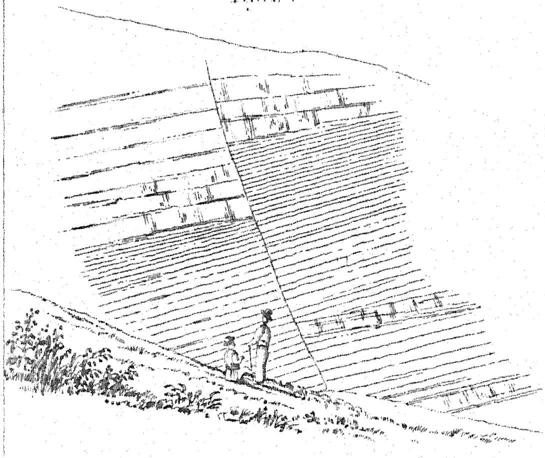
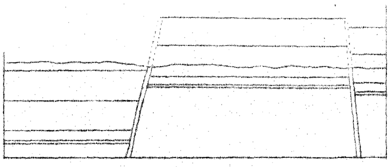


Fig. 20.



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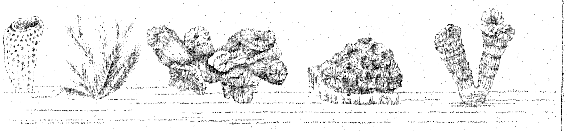

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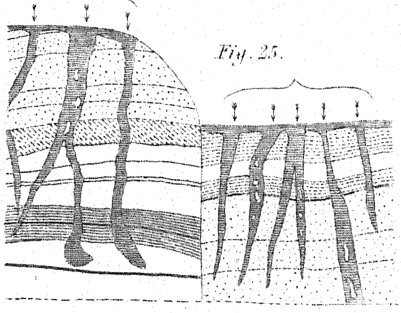

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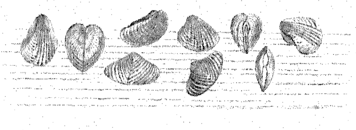

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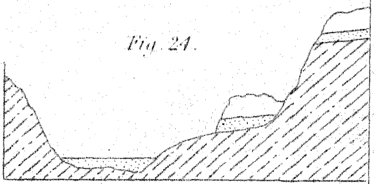

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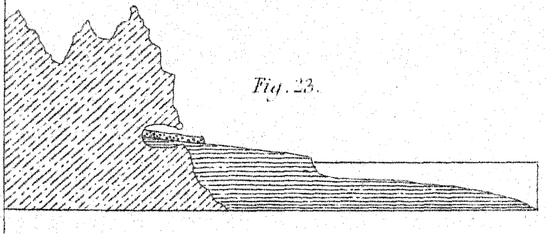


Fig. 27.

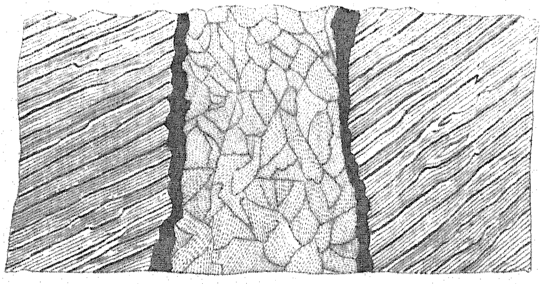


Fig. 28.

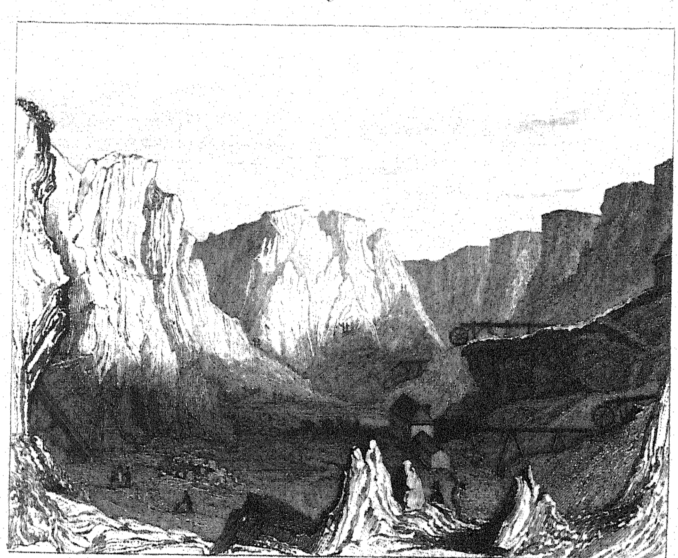


Fig. 29.

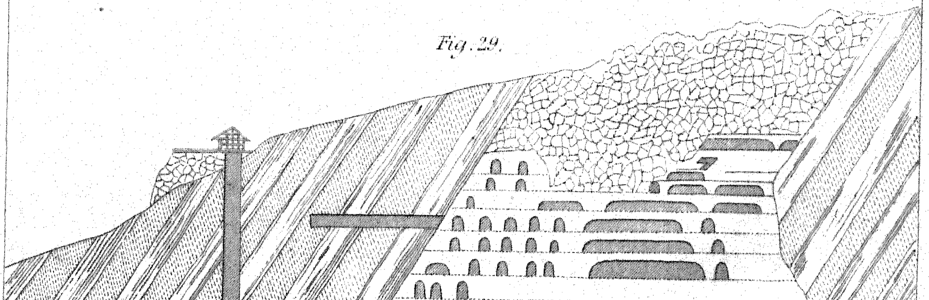


Fig. 30.

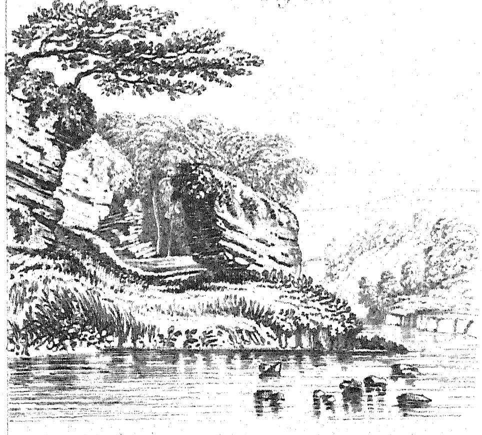


Fig. 31.

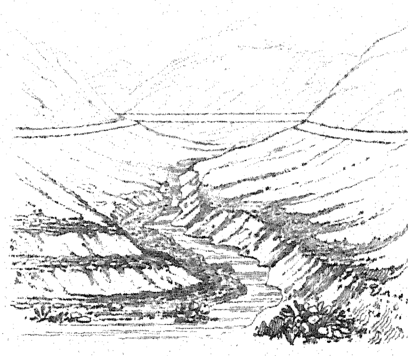
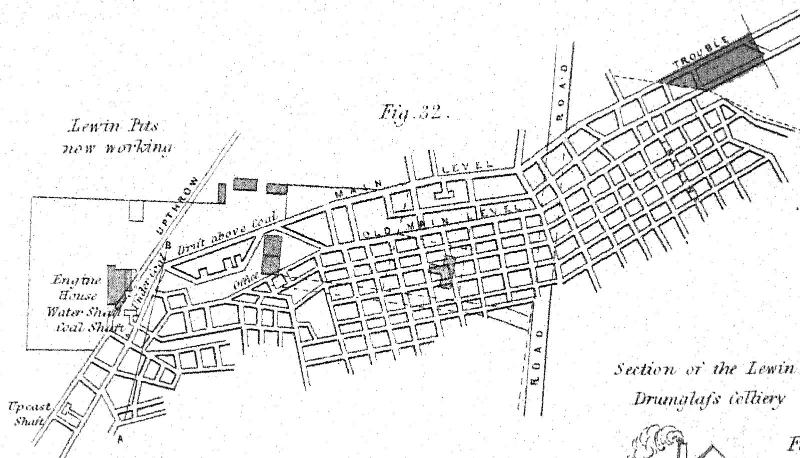
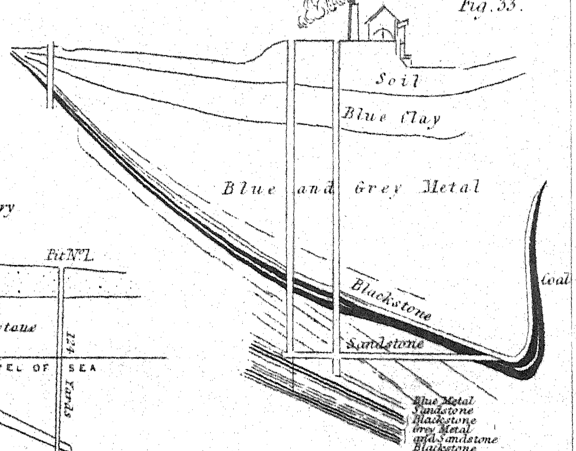


Fig. 32.



Section of the Lewin Pits
Drumglass Colliery

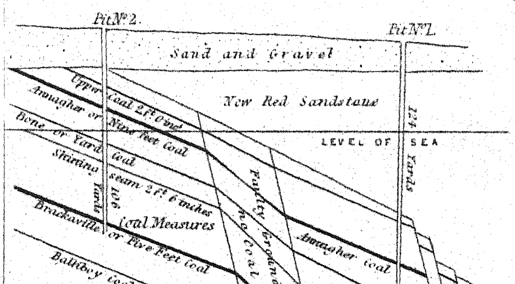
Fig. 33.



SCALE 30 YARDS TO AN INCH

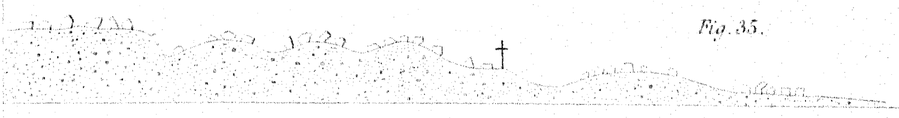
Fig. 34.

Section of Annagher Colliery



SCALE 100 YARDS TO AN INCH

Fig. 35.



Angular Erratics resting on Sand Hills at Degaberga in Sweden.

Fig. 36.
Portlocks Clynometer.

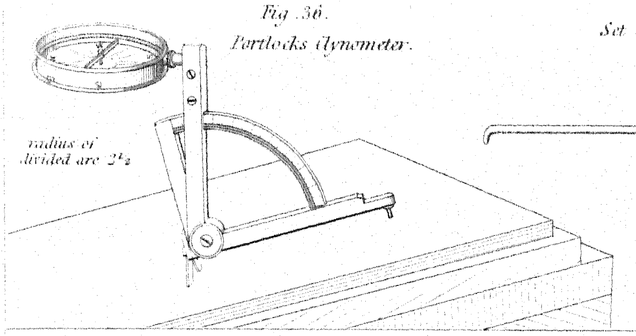


Fig. 37.
Set of Boring Rods.

Fig. 42. Chisel or cutting tool for boring in very hard ground or rock.
Fig. 43. Chisel with central projection to facilitate penetration in hard rock.

BORING TOOLS ON THE ORDINARY SYSTEM

Fig. 38 Open Augur for Stiff Clay.
„ 39 Slightly Opened Augur for Soft Clay.
„ 40 Closed Augur with Valve, for very Soft or Moist Ground.
„ 41 Screw Augur for Hard Ground with Conical Receiver.

Fig. 42.

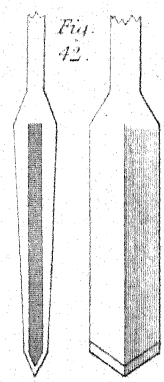


Fig. 43.

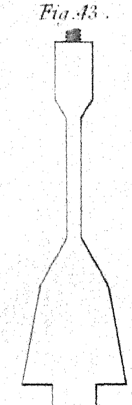


Fig. 38.

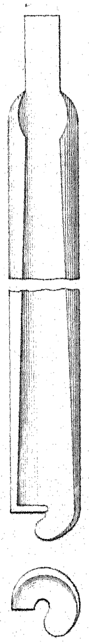


Fig. 39.

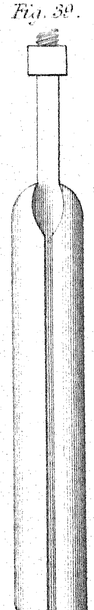


Fig. 40.

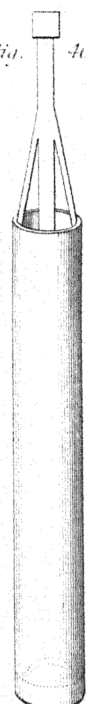
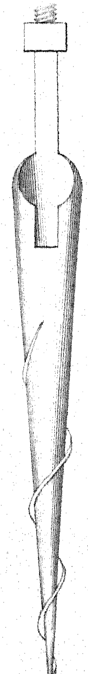


Fig. 41.



J W Lowry fc.

CHINESE OR PERCUSSION BORING.

FIG.45. FRENCH MODE. Croix or double chisel with intermediate cutting joints the earth passes up the grooves of the great impelling weight and lodges in the neck between the projections. FIG.46. GERMAN MODE. The impelling weight is an Iron bar and the earth is received in and brought up by the surrounding cylinder.

FIG.49. BEARTS PATENT 1844.

The hollow boring tube of Fauvelle arranged as a Syphon the water passing from the Reservoir down the Annular Space and ascending up the tube carrying with it the mud or sand disturbed by the cutter or augur. The small exhausting Pump at top is used to draw up the water so as to fill the pipes at first. The Syphon is formed with watertight moveable joints so as to permit the movement up or down.

Fig. 45.

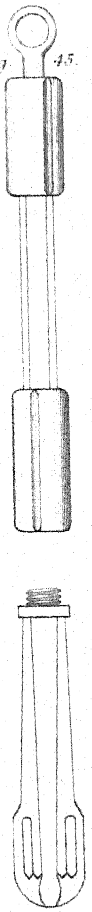


Fig. 46.

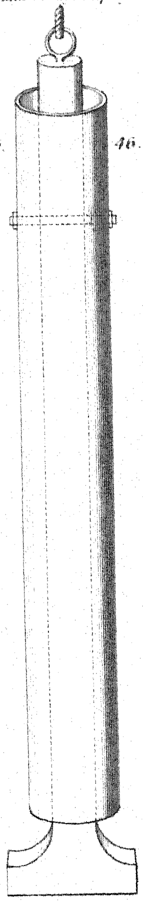


Fig. 49.

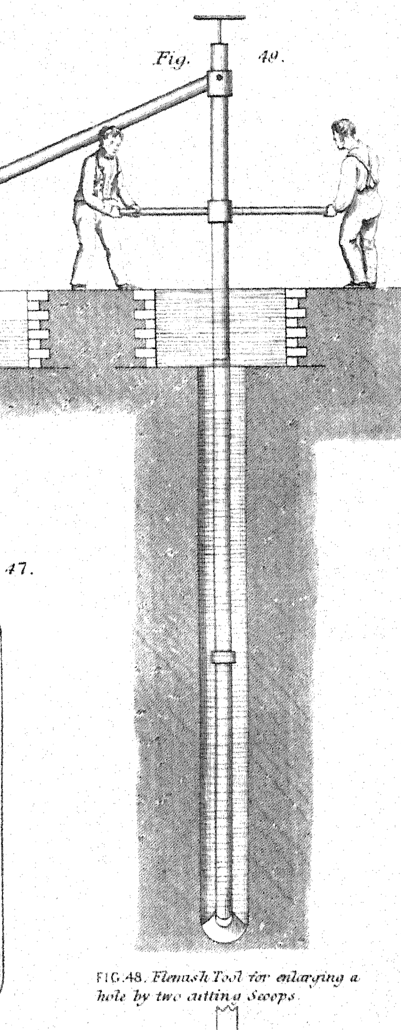


Fig. 47.

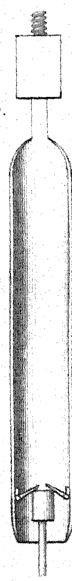


FIG.44. *Large Bucket Augur with valve to bore in loose Gravel.*

Fig. 44.

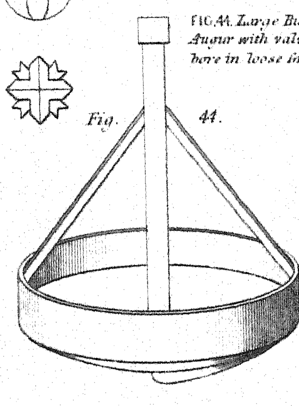
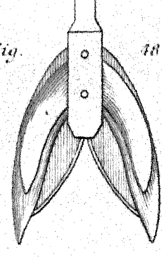


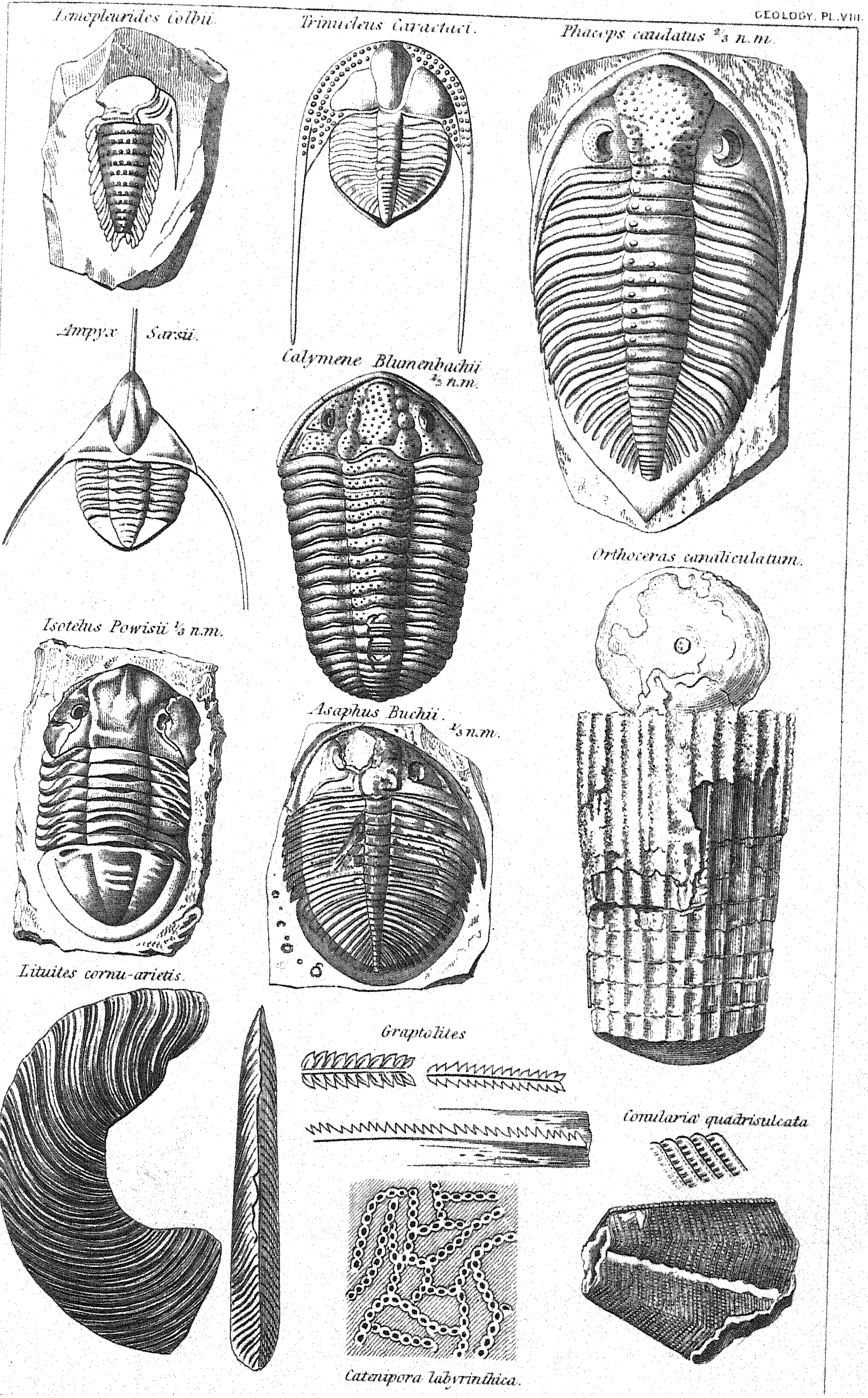
FIG.48. *Flemish Tool for enlarging a hole by two cutting Scoops.*

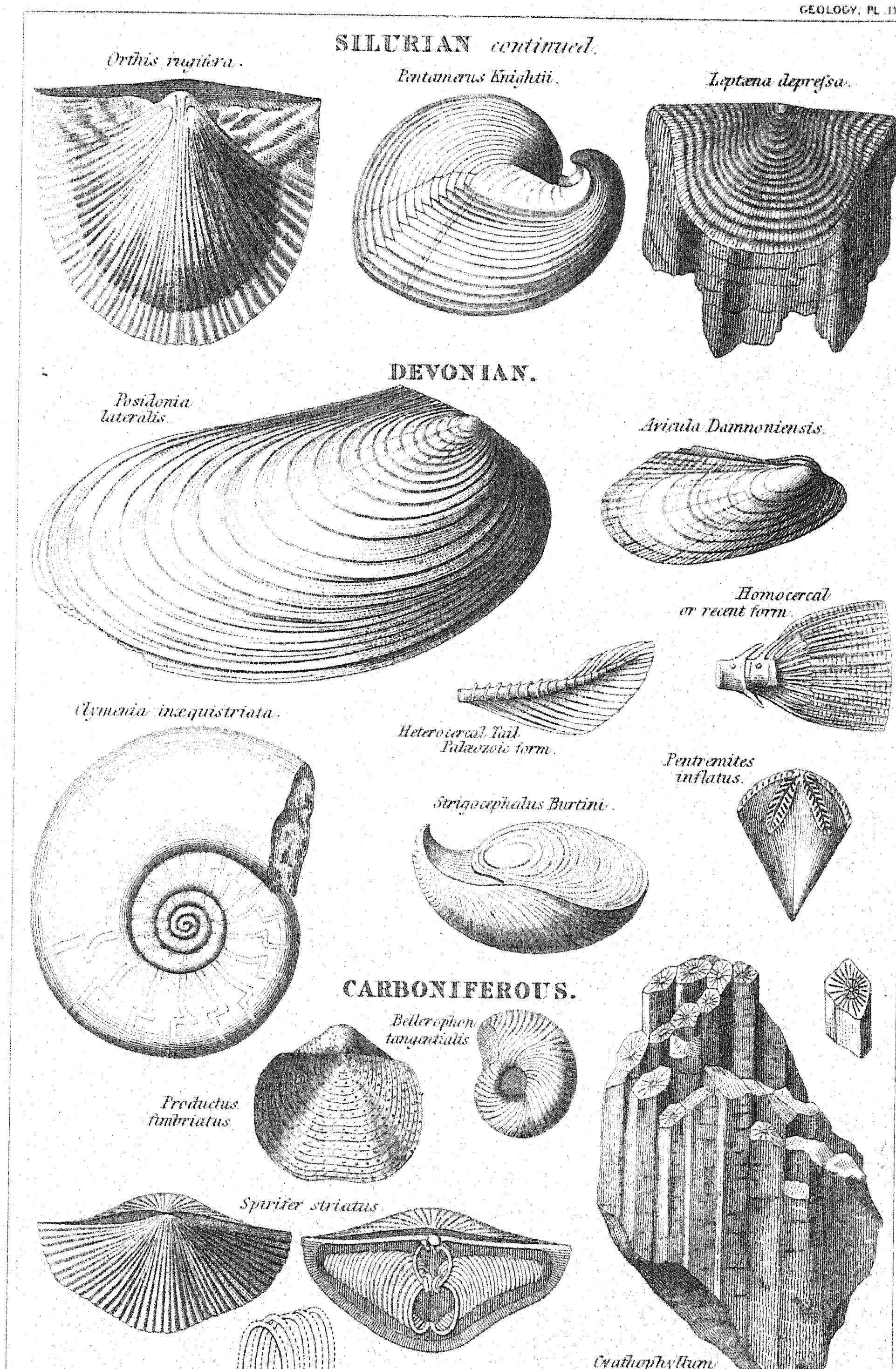
FIG.47. *Tool to draw up a broken Augur the head pushing back the Catches which then hold it fast.*

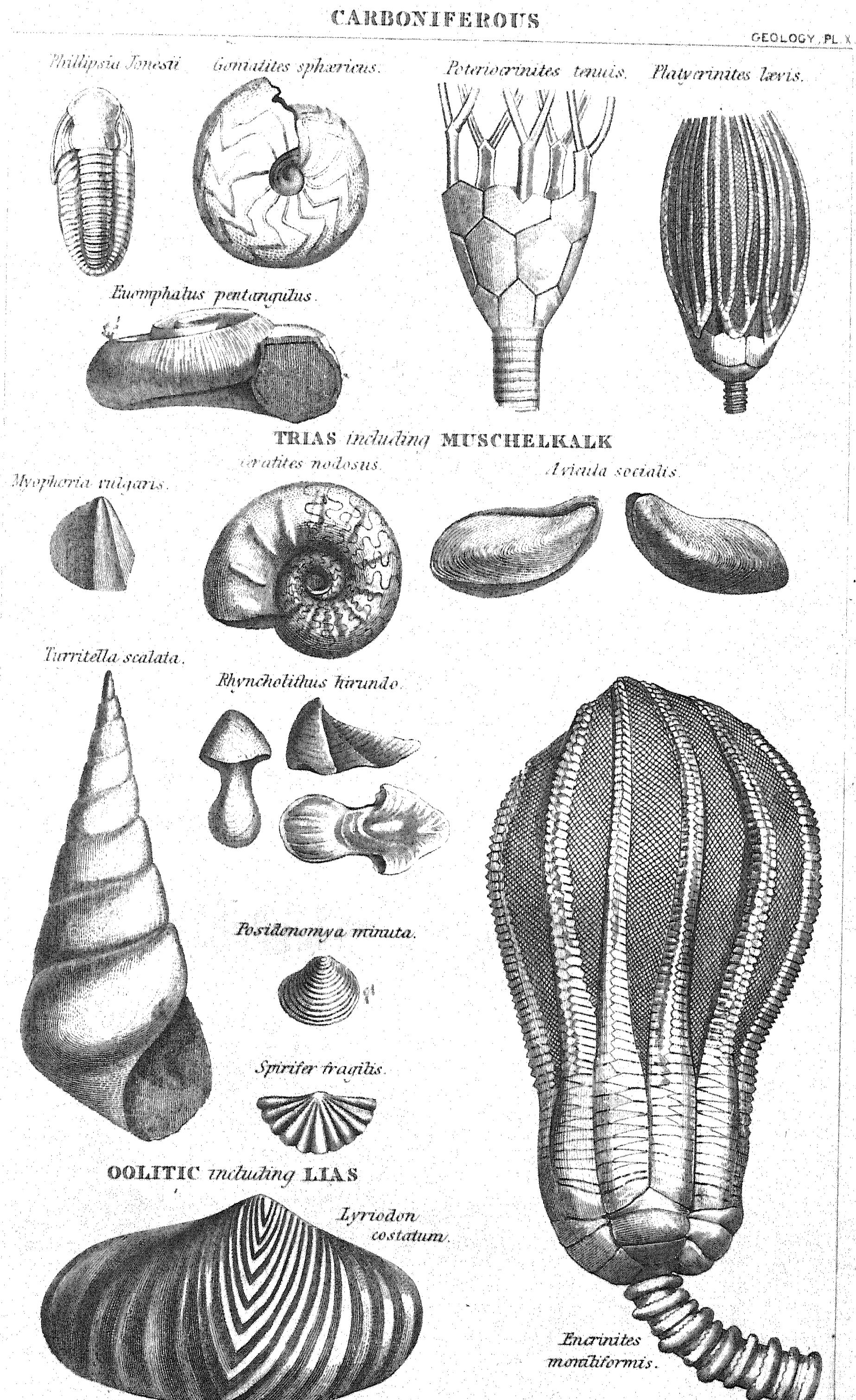
Fig. 48.



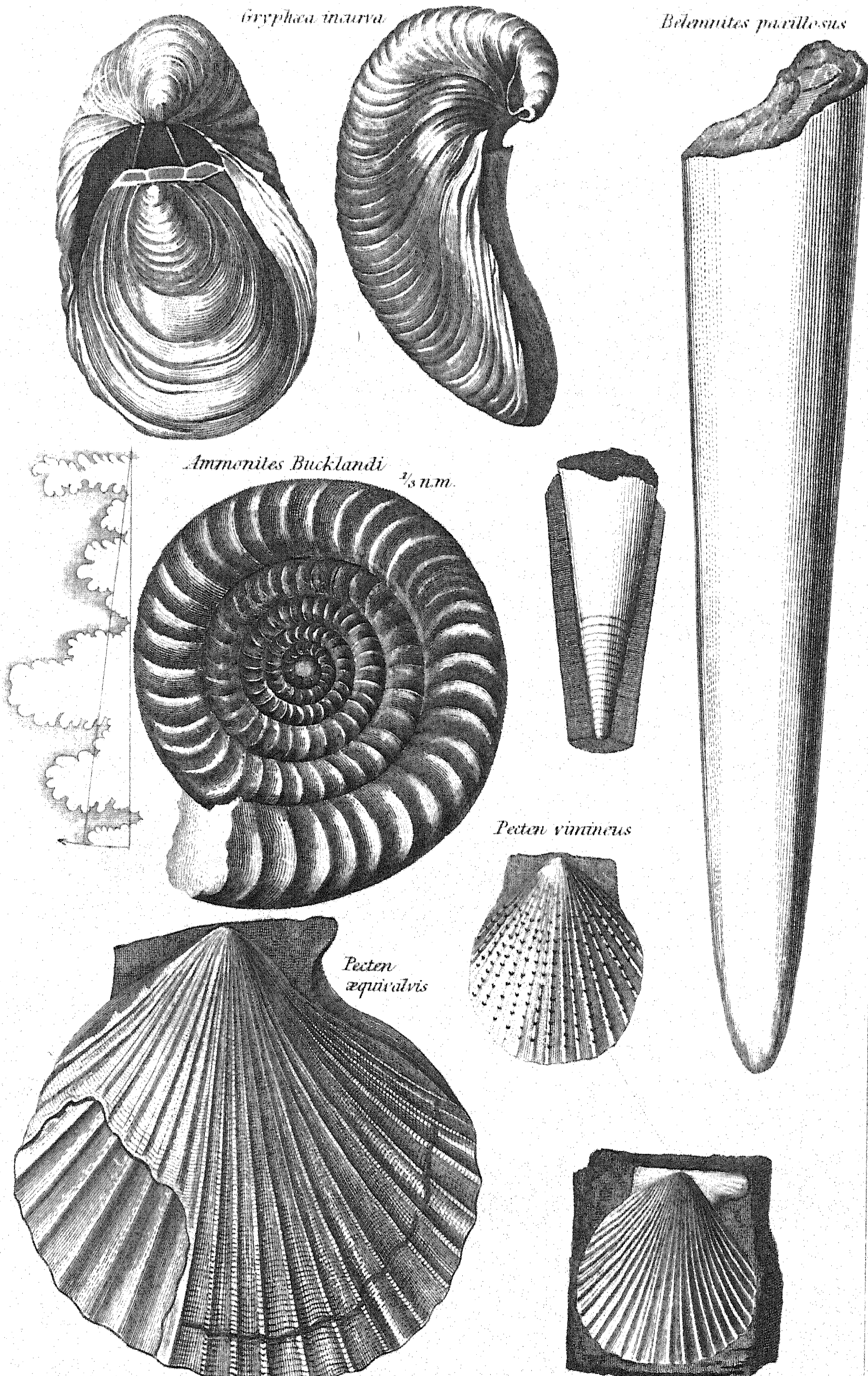
SILURIAN.

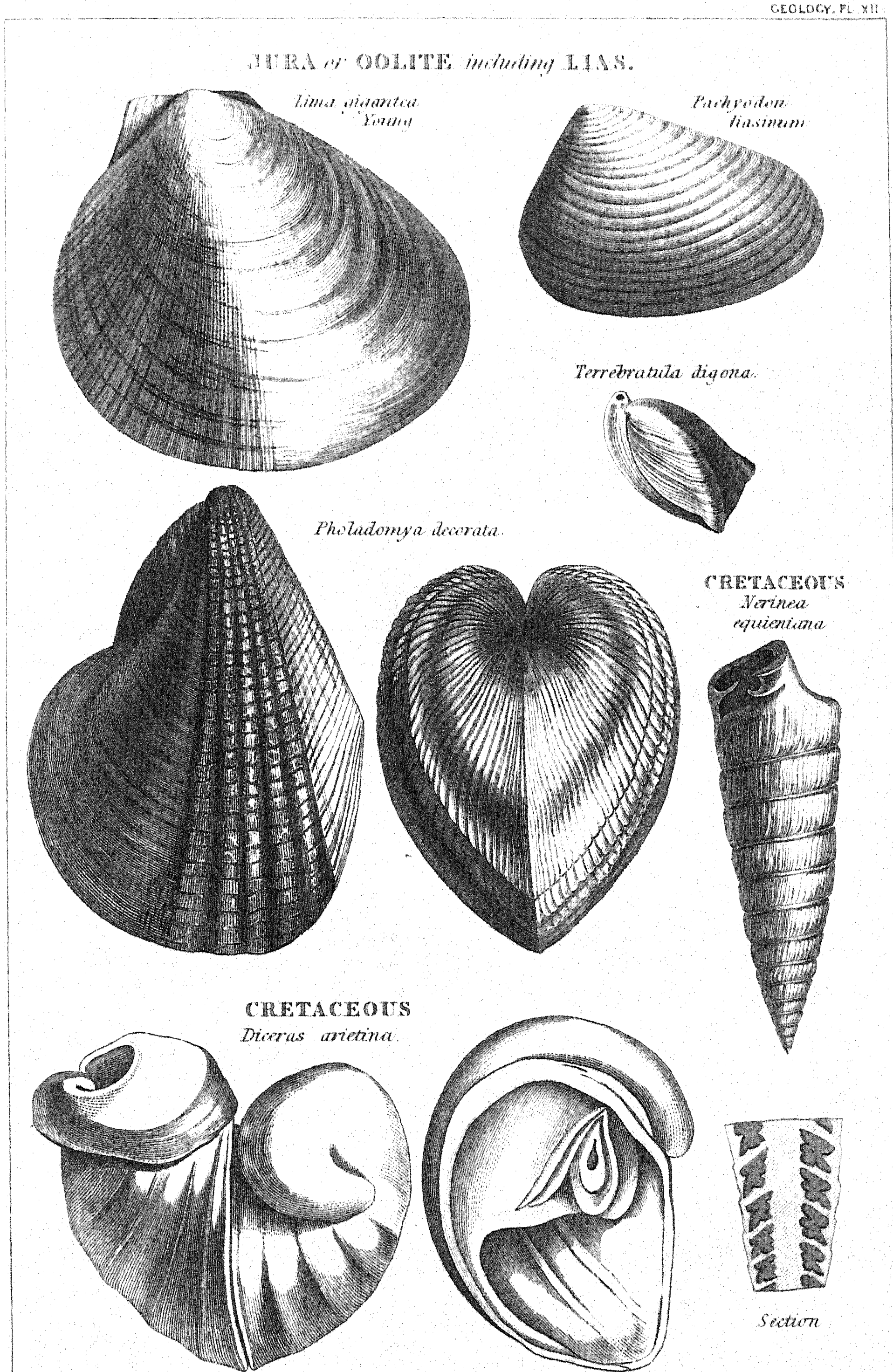

Remopleurides Colbii.
Trinucleus Caractaci.
Phacops caudatus ⅔ n.m.
Ampyx Sarsii.
Calymene Blumenbachii ⅔ n.m.
Orthoceras canaliculatum.
Isotelus Powisii ⅓ n.m.
Asaphus Buchii. ⅓ n.m.
Lituites cornu-arietis.
Graptolites
Conularia quadrisulcata
Catenipora labyrinthica.

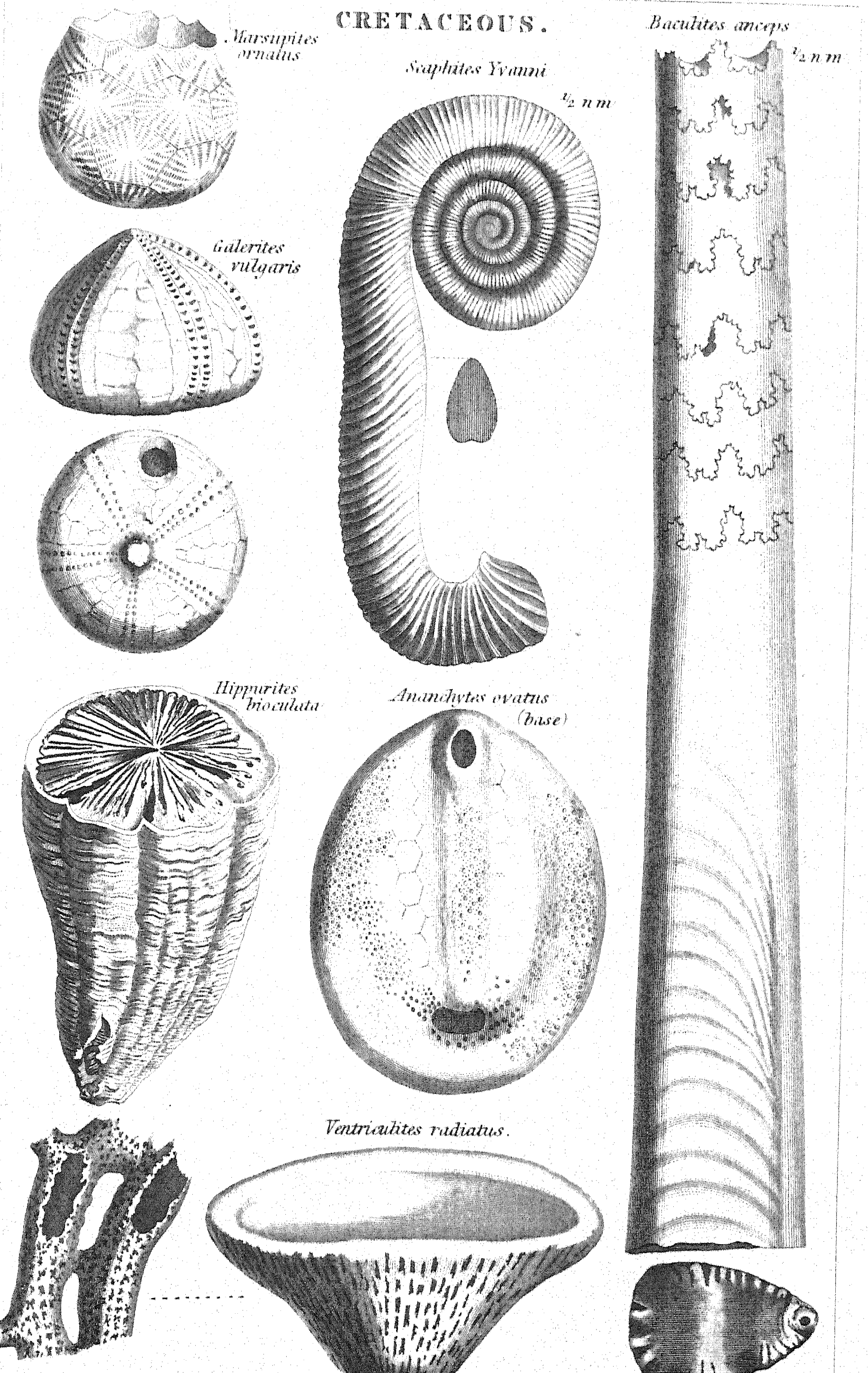

SILURIAN continued.
Orthis rugifera.
Pentamerus Knightii.
Leptæna depressa.
DEVONIAN.
Posidonia lateralis.
Avicula Damnoniensis.
Homocercal or recent form.
Heterocercal Tail Palæozoic form.
Clymenia inæquistriata.
Pentremites inflatus.
Strigocephalus Burtini.
CARBONIFEROUS.
Bellerophon tangentialis
Productus fimbriatus
Spirifer striatus.
Cyathophyllum basaltiforme


CARBONIFEROUS
Phillipsia Jonesii
Goniatites sphæricus.
Poteriocrinites tenuis.
Platycrinites lævis.
Euomphalus pentangulus.
TRIAS including MUSCHELKALK
eratites nodosus.
Myophoria vulgaris.
Avicula socialis.
Turritella scalata.
Rhyncholithus hirundo.
Posidonomya minuta.
Spirifer fragilis.
OOLITIC including LIAS
Lyriodon costatum.
Encrinites moniliformis.

JURA or OOLITE including LIAS.




JURA or OOLITE including LIAS.
Lima gigantea
Young
Pachyodon
liasinum
Terrebratula digona.
Pholadomya decorata.
CRETACEOUS
Nerinea
equieniana
CRETACEOUS
Diceras arietina.
Section
(differs from the Oolitic species by a rounded instead of a sharp keel.)


CRETACEOUS.
Marsupites ornatus
Scaphites Yvanni
½ n m
Baculites anceps
½ n m
Galerites vulgaris
Hippurites bioculata
Ananchytes ovatus (base)
Ventriculites radiatus.

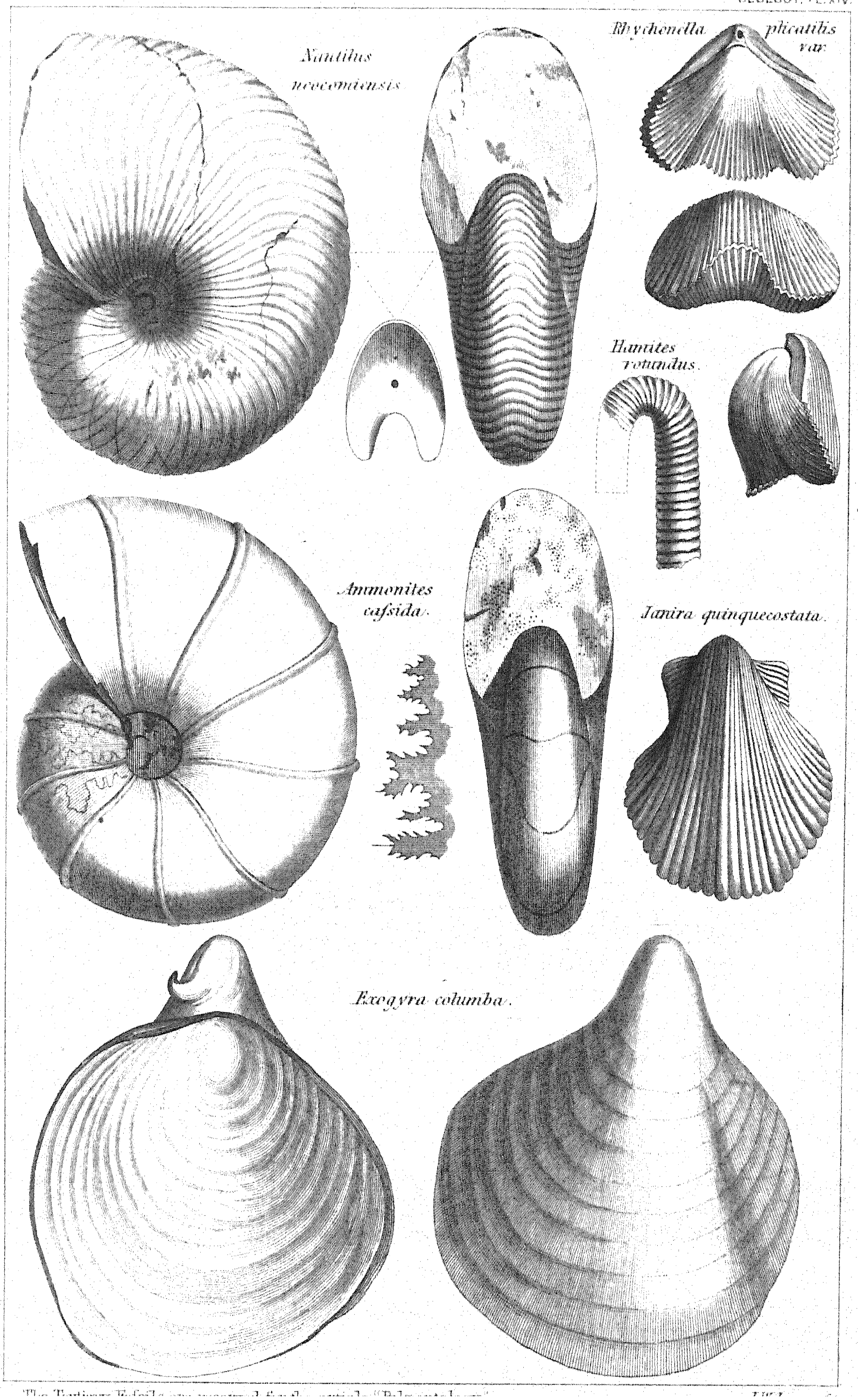

Nautilus neocomiensis.
Rhychonella plicatilis var.
Hamites rotundus.
Ammonites cassida.
Janira quinquecostata.
Exogyra columba.

Table of Dimensions of Grenades.

	GREATEST.			LEAST.		
	pouces.	lignes.	points.	pouces.	lignes.	points.
Exterior diameter	3	6	6	3	5	6
Thickness, aux parois	0	4	3	0	3	9
Thickness, au culot	0	5	3	0	4	9
Diameter at the top de la lumière . .	0	8	9	0	8	3
Diameter at the bottom of do. . . .	0	8	3	0	7	9
Height from the culot to the lumière	3	1	6	3	0	6
Weight	3 lbs. 4 oz.			3 lbs. 2 oz.		

A hand-grenade 3 inches in diameter, weighing 2 lbs. 10 oz., can be thrown by a man to a distance of from 28 to 34 yards (*de* 13 *à* 16 *toises.*)

GLASS HAND-GRENADES.*

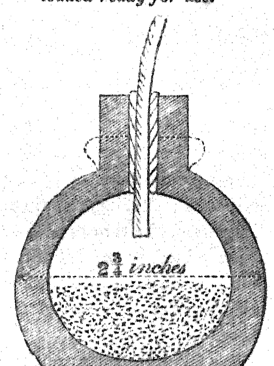
Glass hand-grenades are sometimes made use of with good effect; they are much more portable than those made of iron, and much less expensive.

These grenades are used in Spain at present, and have been since the early part of the 15th century.

They are made of common green bottle-glass, of the dimensions shewn in the accompanying diagram. They produce sharp flesh wounds, and though, like other grenades, more generally used in the *Defence of Posts*, may, from their portability, be easily carried by infantry in the attack of Intrenched Posts, particularly of stockades.

The accompanying diagram represents the grenade now in use in Spain, with the exception of the fuze, which is here shewn as Bickford's slow-burning fuze, instead of the common tubes used in Spain, which are apt to go out in the neck of the grenade, and not explode.

Section of a Glass Hand-Grenade, loaded ready for use.



The projecting neck of this grenade may, I think, be shortened with advantage, as shewn by the dotted line, as it is the part most liable to be broken, if it come in contact with a rock or wall when thrown from a height: the soldier should be instructed in those cases to roll it, whenever he can do so. A man can throw this grenade from 30 to 40 yards.

The weight of a glass hand-grenade is 10½ oz., or ⅓ that of an iron one, when loaded with one ounce of powder, or a common musket cartridge, and about 2 inches in length of the slow-burning Bickford's fuze fitted into the neck, as shewn in the diagram; a little tow being wrapped round it, if necessary, to make it tight.

I have no doubt on further trial, both with powder and gun cotton, a much smaller space will be found sufficient for the charge, and that the glass may be proportionately increased in thickness, thereby giving larger splinters, and doing more damage.

In the manufacture of glass hand-grenades, the ***greatest possible attention*** must

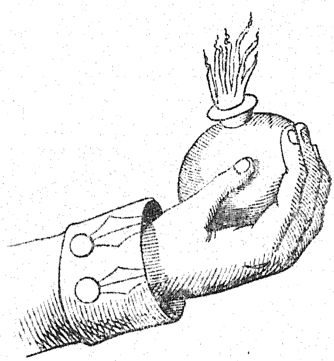
* By Lieut.-Colonel Alderson, R. E.

be paid to the *annealing process*, as without this is *thoroughly* done, they will, on bursting, fly into thousands of minute particles, and become harmless.

METHOD OF LOADING AND OF THROWING GRENADES.*

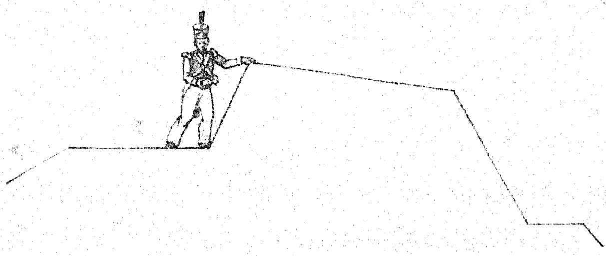
The instruction is commenced by burning some fuzes between the finger and thumb, to shew the party how long they burn, and that in the fuze itself there is no explosion, or danger.

The grenade is held as in the subjoined sketch.



When it is lighted, the necessity must be explained of keeping the fuze turned towards the front, and a little downwards, until after the small explosion of the priming of the fuze, which is liable to burn and annoy the men who may be next the grenadier.

The manner in which the grenade is held until after that small explosion will be as represented in the annexed figure; the port-fire burning immediately below it on the banquette.



After this has been fully explained to the party, they should be practised in throwing empty grenades, both from a work and into one, standing fast, and going through the motions of lighting the fuze each time a grenade is thrown. It is to be done with a pitching, or swinging throw. After practising thus with empty grenades, a few should be thrown with fuzes; and after lighting them, they should be made to pause a little before they throw them, in order to teach them coolness. The party return again to practise with empty ones, continuing thus to throw empty grenades and grenades with lighted fuzes by turns, until they become expert in throwing them.

The following is the weight of loaded grenades and small shells:

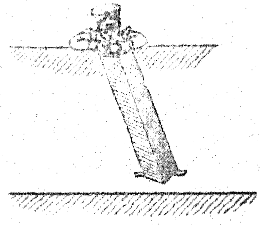
	lbs.	oz.
The Land Service hand-grenades weigh	1	13
The Sea Service grenade	4	2
The 4⅖-inch shell	10	0
The 5½-inch shell.	16	0

The first is the best for the attack of works; but the 4⅖-inch shell is the most convenient for the defence.

The 5½ and 4⅖-inch shells are thrown over hand, in the manner called 'putting.'

* Chatham practice.

Shells heavier than 5½-inch cannot be thrown by the hand, and therefore they require a smooth surface, for the purpose of rolling them over the parapet.

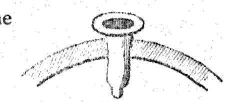


To form a run for heavy shells, take two planks and connect them together by a couple of smaller pieces of wood, in the same manner as is usual in making wooden gutters or spouts. The shell being placed in the trough, as in the annexed figure, may then easily be rolled over the parapet.

Grenades for Service are filled full of powder, but for exercise the following quantities are used, for blowing out the fuzes:

	Drachms.
Land Service grenades	6
Sea Service	9
4⅖-inch shell	10½
5½-inch shell	12

This small charge is put into a cartridge and fixed to the bottom of the fuze in driving it thus.



Fuzes are made of the following materials:

	lbs.	oz.
Saltpetre	3	4
Sulphur	1	0
Mealed powder	2	12

This proportion is to be well mixed with the hands, then run four times through a fine hair sieve, and mixed a second time.

The following Tables and Directions are chiefly extracted from the 'Pocket Gunner:'

Table for driving Fuzes.

Nature of Fuze.	Weight of Composition.	Nature of Ladles.	Number of blows to each ladleful.	Number of threads of quick-match for each.	Number each man drives per diem.	Time each will burn.
inch.	oz. dr.	oz. dr.	number.	number.	number.	seconds.
13	2 8	2 0	21	4	9	35 to 38
10	1 8	1 0	18	4 or 3	9	33 35
8	1 0	0 8	15	3	12	29 31
5½	0 6	0 6	13	2	16	18 21
4⅖	0 6	0 4	12	2	16	15 17
Hand-Grenade	0 3		10		28	

Table shewing the Dimensions of Fuzes.

Nature.	Diameter of the Fuze.			Diameter of the Composition.		
	Below the cup.	At the bottom.	At the cup.	Diameter.	Length.	Time it burns.
inches.	inches.	inches.	inches.	inches.	inches.	seconds.
13	2·1	1·575	2·49	·5	8·4	35
10	1·8	1·35	2·13	·438	7·2	33
8	1·3	1·25	1·78	·375	6·37	29
5½	1·1	·825	1·3	·275	4·4	18
4⅖	1·0	·75	1·18	·25	3·5	15
Grenades	0·8	·6	·9	·2	2·25	

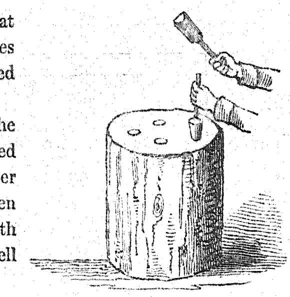
Diameter inside the cup is 3 diameters of the bore.

Depth of the cup, $1\frac{1}{2}$ diameter.

Thickness of wood at bottom of the bore, 2 diameters.

The articles necessary for driving fuzes are, large blocks of wood with holes at top, in which the fuzes are to be fixed, proper mallet, iron drifts tipped with brass, copper ladles of each nature, square boxes for holding the composition; in addition to which must be provided quick-match and mealed powder.

In driving fuzes, the principal points to be attended to are,—to put in equal quantities of composition each time, which is effected by passing a round stick over the edges of the ladle,—to take off the compositions along the edges, and to keep the stroke as steady and regular as possible, giving always the same number to each ladleful.

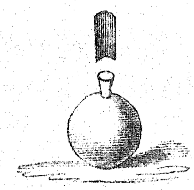


The drift is held in one hand, turning it round at each stroke, the fuze being kept steady in the holes by small wedges, if necessary, as in the annexed figure, which represents the process of driving.

The fuzes must always be driven nearly to the height of the cup. They are afterwards primed with quick-match, and a ladleful of mealed powder put over it, which must be driven down with fifteen strokes of the mallet, and the cup filled up with mealed powder, moistened with spirits of wine, well pressed in with the finger.

The fuze is driven into the grenade by a few sharp blows of the mallet.

In fixing the fuze to the grenade, it is first pushed in by the hand; afterwards a round piece of wood having a conical hole at bottom is placed up the top of the fuze, to prevent the priming from being injured; and then the fuze is driven firmly into the shell-hole, by a few smart blows of the mallet upon the head of the driver, which is represented in section in the annexed figure.*



In two or three days, when the mealed powder is dry, fuzes intended to be kept in store for any length of time must have a circle of paper fitted to the top of the cup, and a cap of brown paper, or painted canvass, tied over all.

The following expedients may be used for defending ramparts in place of hand-grenades, viz. sound stone bottles, soldiers' wooden canteens, leather bags, canvass bags pitched over to prevent accidents, small tin cases, &c. By attaching a fuze to each of them, they may be thrown in the same manner as grenades.

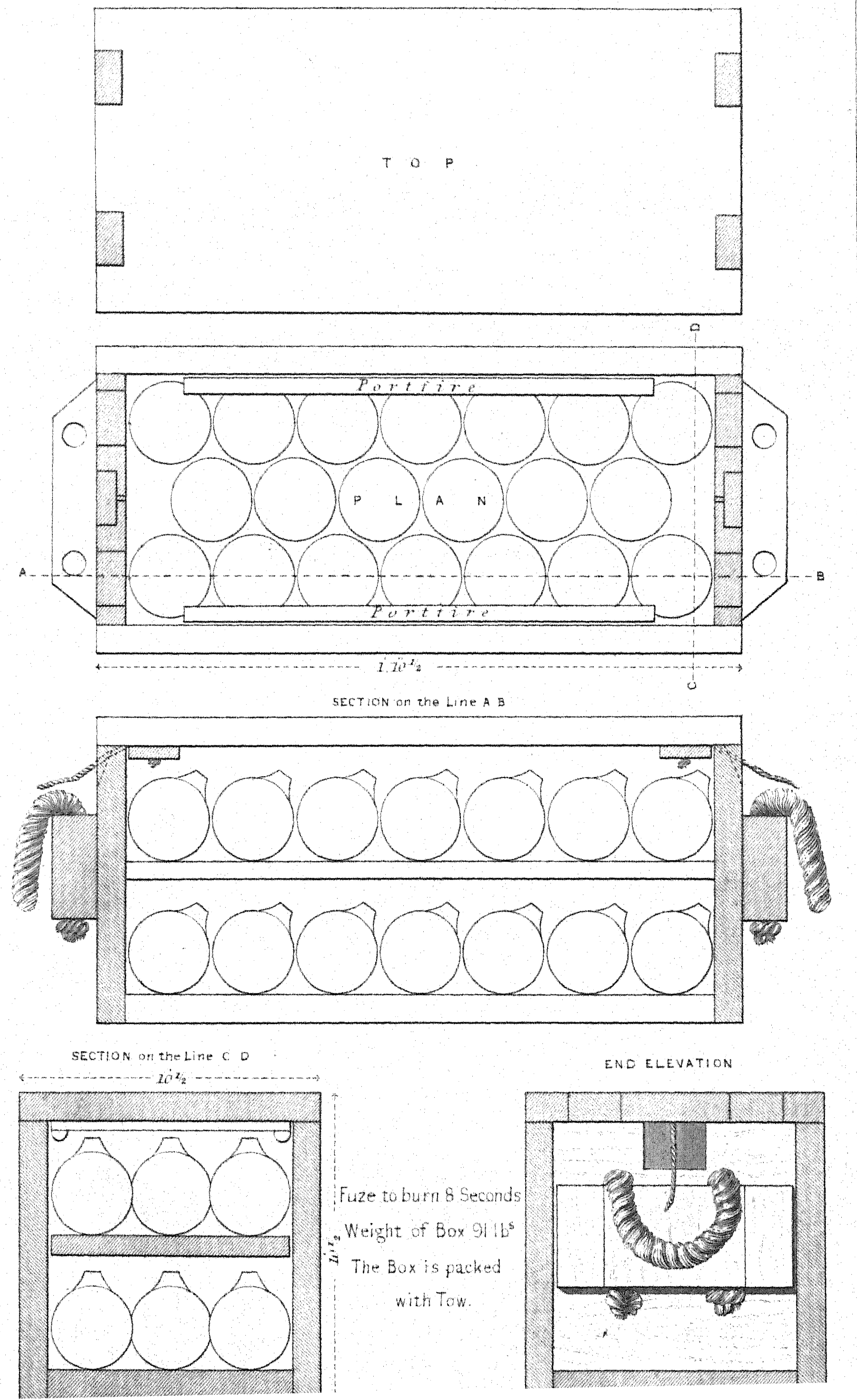
GUARD-HOUSE, DEFENSIBLE.—Usually constructed of masonry, for the defence of *Flèches*, *Redoubts*, and *advanced works*, as likewise for the security of *Coast Batteries* and *Isolated Posts*.

Defensible Guard-Houses are not generally placed where a resistance is expected beyond a few hours, support being usually within a moderate distance; except in very peculiar sites, such as the gorge of a mountain inaccessible for artillery, or at the end of a causeway or morass, out of cannon-shot.

When constructed as an inner defence, defensible guard-houses should be well

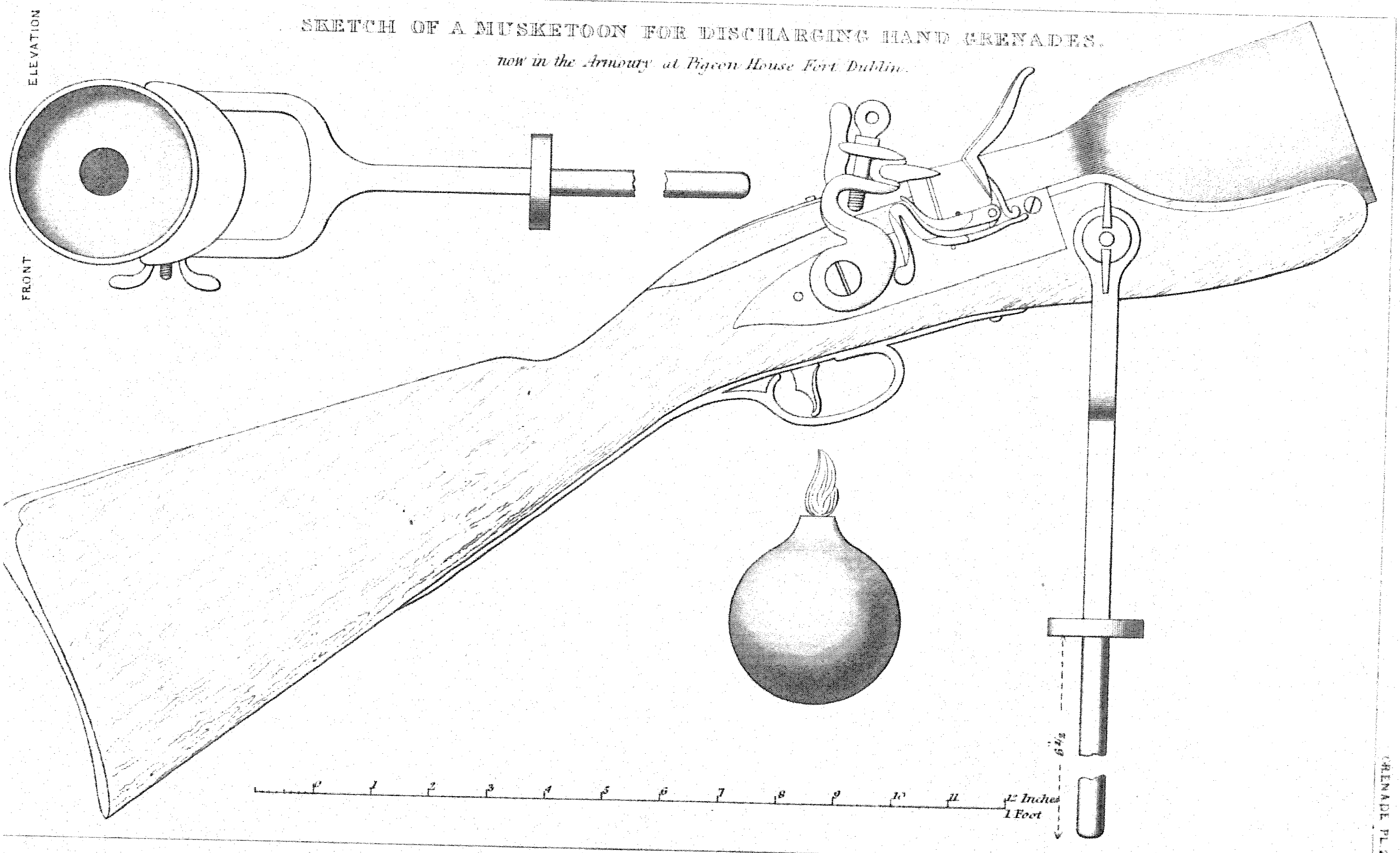
* Some tow is usually placed between the fuze and the driver, to prevent the fuze from splitting.

PLAN SECTIONS AND ELEVATION OF A BOX CONTAINING 40 HAND GRENADES FOR LAND SERVICE



SKETCH OF A MUSKETOON FOR DISCHARGING HAND GRENADES.

now in the Armoury at Pigeon House Fort Dublin.



covered by the work: the building is intended to serve as a keep, and it should be incombustible, loopholed, and the entrance well secured.

Figs. 1 and 2 are examples adapted to redoubts, flèches, and advanced field-works of a permanent nature; and if there is sufficient time, the entrance should be secured with a draw-bridge, well flanked by musketry fire.

Fig. 1.

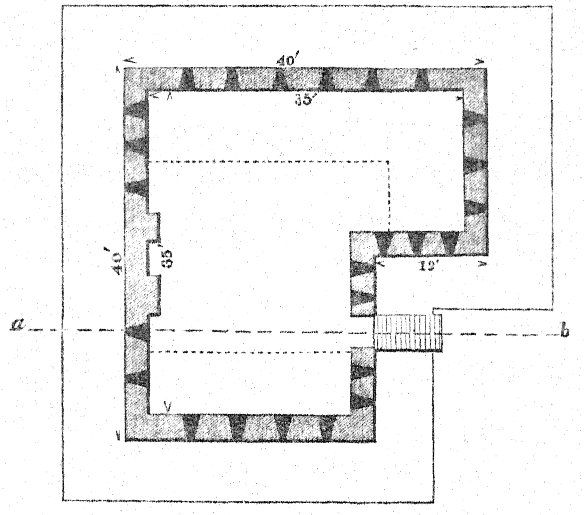
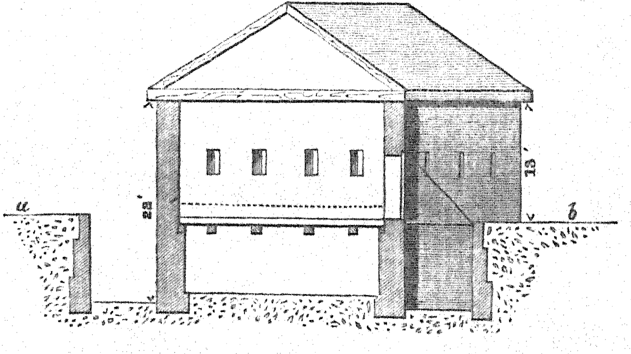
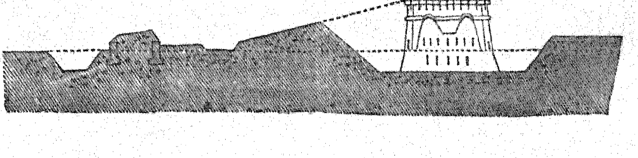


Fig. 2.



Figs. 3 and 4 are suited to coast batteries, taken from the French as a normal construction, for the protection of sea defences: for further detail see third volume of 'Professional Papers.'

Fig. 3.



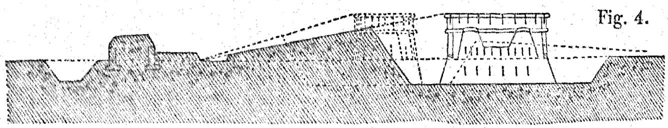


Fig. 4.

Figs. 5 and 6 give the designs for a Cavalry Picket Guard-House in the mountains, where artillery cannot be brought against it; *a*, fig. 5, serving as the kitchen; *b*, men's room; *c*, lobby and guard-room; *d*, stables; and over the kitchen is an officer's room, and over the lobby a store, as shewn in fig. 6.

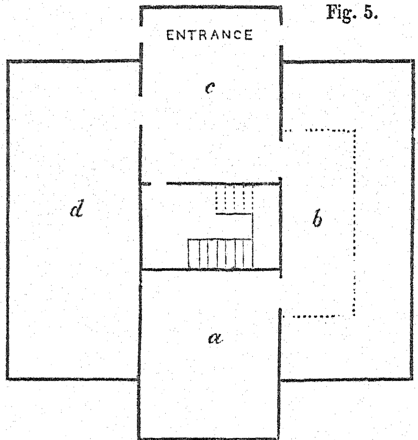
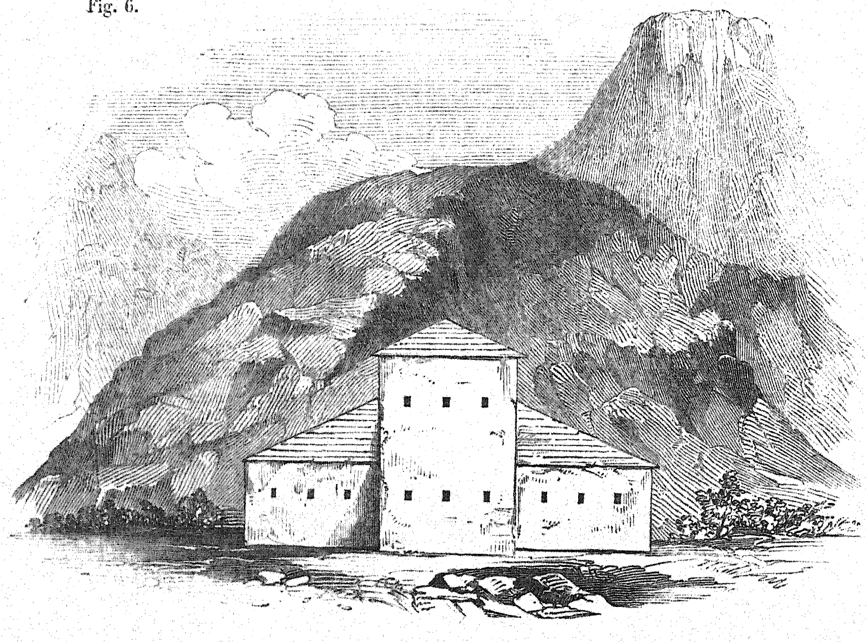


Fig. 5.

Scale, 20 feet to an inch.

Fig. 6.



Figs. 7, 8, and 9, are Picket Towers, mounting a field-piece placed on the frontier of the Cape of Good Hope, for the protection of the advanced posts.

Fig. 7.—Barrack Floor.

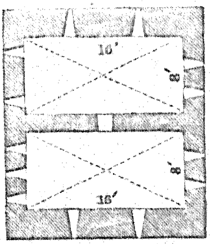


Fig. 8.

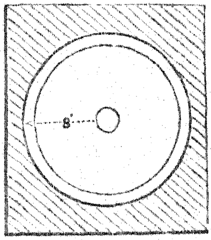
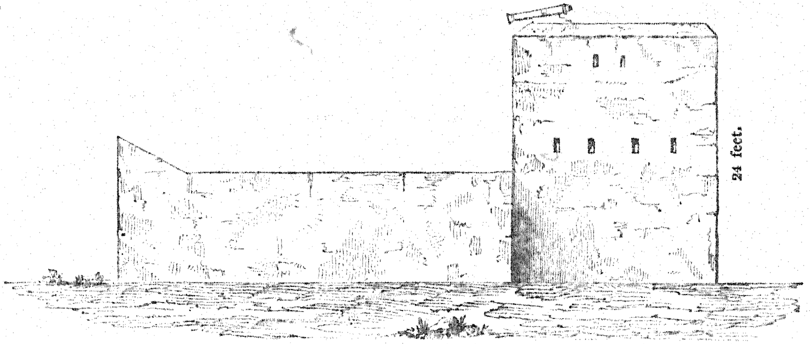


Fig. 9.



Scale, 20 feet to an inch.

Figs. 10 and 11 give a design of a Draw-Bridge adapted to the above works, when draw-bridges are required, taken from a design by Lieut. Douglas Galton, R.E.

The principal advantages of this method are,—

1. That *theoretically* the counterpoise balances the platform in any position.

2. When the bridge is raised, the counterpoise acts as a gate. When the bridge is lowered, the counterpoise should be supported by a bolt; and when raised, the counterpoise should be secured in its vertical position.

Fig. 10.

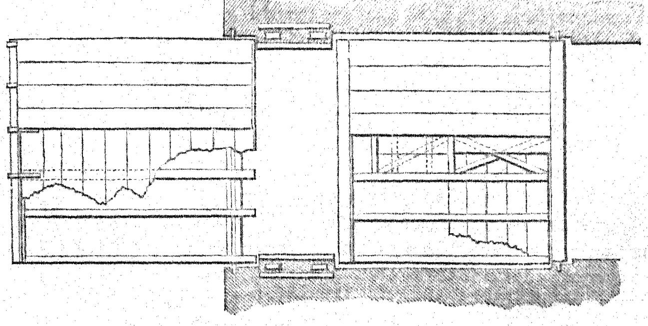
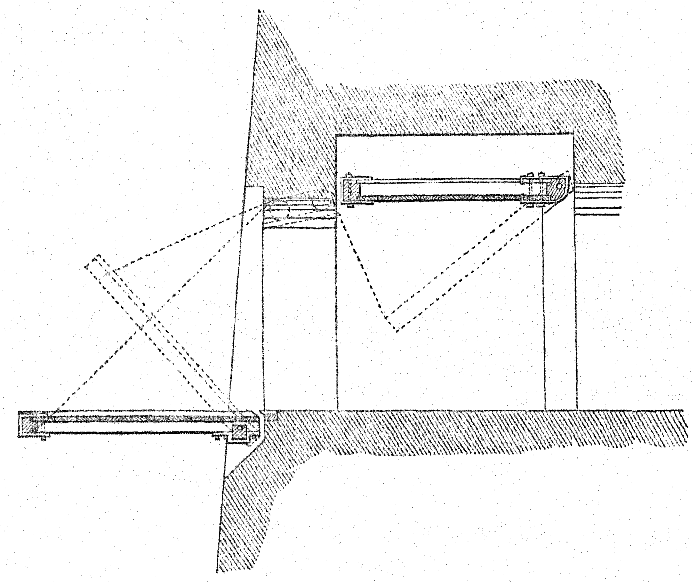


Fig. 11.



Scale, 8 feet to an inch.

The counterpoise is generally made rather ~~higher~~ lighter than the bridge; the axis of the latter is sometimes placed a little forward, that when the bridge is raised, it may rest against the escarp, without danger of falling down, if the chains should break; in which case, to lower the bridge, two men (or if a heavy one, four men) pass through the wicket in the counterpoise, and push down the platform of the bridge.

The platform is prolonged beyond the axis, to do away with the necessity of a moveable board.

By using two rollers for the chain to pass over, the friction (vis inertiæ at first starting) is much diminished.

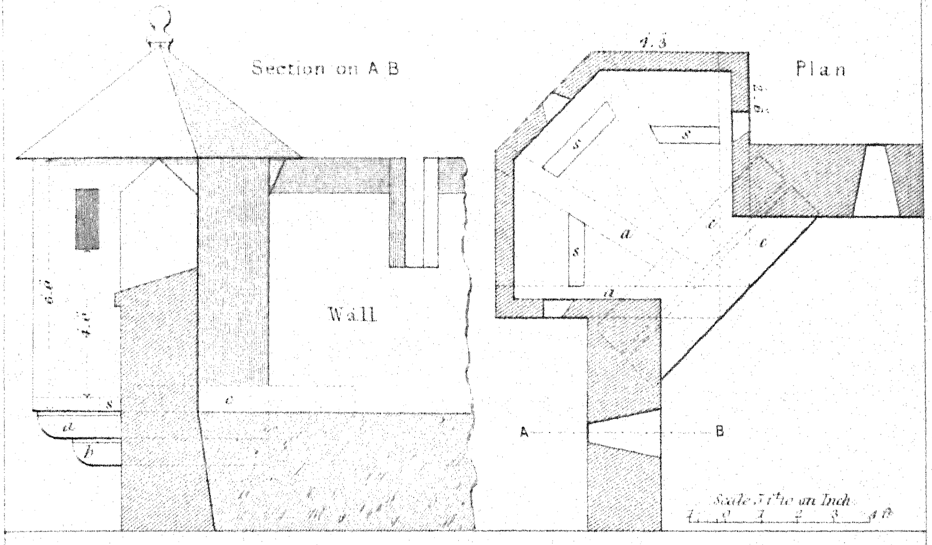
GUERITE,* (called also Echauguette.)—This term was originally applied to the projecting stone or brick sentry-boxes or turrets, sometimes built at the top of the revetments of the salient angles of works in fortresses, the object of which is to enable sentinels placed in them to command thoroughly the ditches in front through loopholes, without being exposed to the enemy's musketry fire: they are, however, considered objectionable from their marking the position of the salients and facilitating the taking up the prolongations of the works by an assailant, for the purpose of enfilading their terrepleins.

In placing ordinary enclosures in a state of defence, similar buildings may often be constructed with advantage, to give a flank defence to lines of wall forming the boundary of a road or river where projecting works could not be built on the level of the ground for that purpose, or where, as in a dead re-entering angle, or over an entrance, a perpendicular or machicoulis fire is required.—(See 'Machicoulis.')

Figs. 1 and 2, of Plate 'Guerite,' shew the mode of construction of a brick guerite

* By Captain Bainbrigge, R. E.

GUERITE

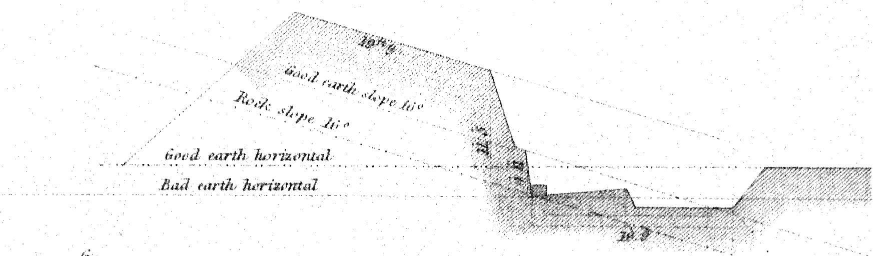


GENOUILLERE

(see platform.)

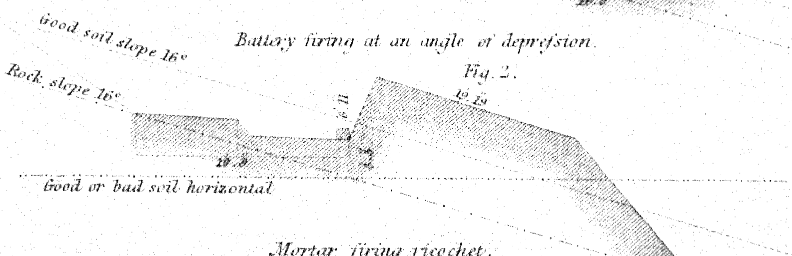
Battery firing at an angle of elevation.

Fig. 1.

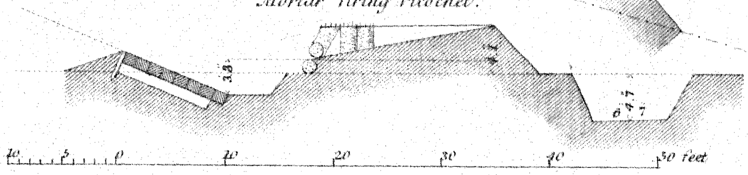


Battery firing at an angle of depression.

Fig. 2.



Mortar firing ricochet.



excess of acid is to be drawn or poured off, and the cotton pressed lightly with an earthen presser, so as to separate the principal part of the acid. The cotton is afterwards covered over, and allowed to remain for one hour: it is then pressed, and thoroughly washed in running water, to divest it of all free acid, until it does not in the least degree affect litmus paper: it is then to be partially dried, by pressure; and to insure its freedom from acid, it is to be washed in a dilute solution of carbonate of potass, made by dissolving one ounce of carbonate of potass in a gallon of water: it is then put under a press, and the excess of the alkaline solution pressed out, while at the same time the cotton is rendered nearly dry. In the next place, the substance is washed in a solution consisting of one ounce of pure nitrate of potass in one gallon of water; and when again pressed, is dried in a stove, or room, heated by steam, or hot water, to the temperature of from 150° to 170° Fahr. The nitrate of potass seems to increase the explosive force of the cotton; but it is not absolutely necessary. In using the cotton prepared as above, it must be borne in mind, that to produce the same effects much less must be used than of gunpowder; that is, in about the proportion of three parts of the prepared cotton* to eight parts of Tower-proof gunpowder.

"Explosive cotton may be prepared by using nitric acid only; but the patentee prefers using the above mixture of nitric and sulphuric acids.

"In using cotton prepared as above for the purposes of propulsion, as it is of a fibrous nature, it may be rammed at once into the gun; or, if made slightly moist, and then pressed into a mould, it will, when dry, retain its form, and thus may be made into cartridges.

"The patentee does not confine himself to the specific gravity of the acids above mentioned, nor to the exact process herein described; but what he claims is the converting vegetable matters into explosive substances, by means of nitric acid."—(*From the Patent Journal of April 17th*, 1847.)

Upon the publication of the specification, of which the foregoing is the substance, it was found that the chemists whose attention had been directed to the manufacture of gun cotton during the previous six months, had not only been able to make an article *resembling* Schönbein's, but in many instances had fallen upon his *precise* method. It is true that Professor Otto proposed the employment of *nitric acid* alone; but as we stated before, his method laid the foundation of the success of future manipulators. His directions were: "In the preparation of the exploding cotton, common well-cleaned cotton is dipped, for about half a minute, in highly concentrated nitric acid, (the acid which I use being made by the distillation of ten parts of dried saltpetre and six of oil of vitriol;) and then instantly placed in water, which must often be renewed, in order to free the cotton from the acid with which it is impregnated. Care must be taken that all the knotty particles of the cotton are properly disentangled, and that it is thoroughly dried. After this, the explosive preparation is ready for use."

This plan of Professor Otto did not produce a very good cotton; besides, the difficulties and expense attendant upon the preparation of the acid were too great.

In the 'Times' newspaper of the 17th and 26th of October, 1846, appeared two letters from Mr. Thomas Taylor, of New Bridge Street, Blackfriars, in which he de-

* Gun cotton can be exploded by galvanic electricity, under precisely the same circumstances as gunpowder. The common electric spark will also ignite it, under the following arrangements. If an electric spark from a battery be allowed to fall upon a mass of gun cotton, it will produce *no effect*; but if the fluid be retarded in its progress, by being conducted over the surface of a piece of string, moistened with common water, and placed in contact with the cotton, an explosion takes place.—J. R.

tailed a successful method of preparing the cotton, by the action of mixed nitric and sulphuric acids; acknowledging, at the same time, that his plan was merely a modification of Dr. Otto's. As the mode adopted by Mr. Taylor was a very simple one, and was very similar, in its character, to that employed by the Author of this Paper, as well as by other scientific men, we shall give it here as briefly as possible. "Mix in any convenient glass vessel, one ounce and a half, by measure, of nitric acid, (sp. gr. 1·45 to 1·50,) with an equal quantity of sulphuric acid, (sp. gr. 1·80.) When the mixture has cooled, place 100 grs. of fine cotton wool in a Wedgewood mortar, pour the acid over it, and, with a glass rod, imbue the cotton as quickly as possible with the acid. As soon as the cotton is completely saturated, pour off the acid, and with the aid of the pestle, quickly squeeze out as much of the acid as possible. Throw the mass into a basinful of water, and thoroughly wash it, either in successive portions of water, or underneath a tap, until the cotton has not the slightest acid taste. Finally, squeeze it in a linen cloth, and dry it in a water bath."

In making the explosive cotton, a much greater amount of fulminating power may be obtained by using a larger relative proportion of the acids to the cotton; or by using a stronger nitric acid. Nitric acid of the sp. gr. 1·50 answers much better than that of 1·45; it being a curious fact, that the cotton is much less acted upon by the strong acid. Thus nitric acid of sp. gr. 1·36 converts the cotton into a gelatinous mass.

It will be observed that the plan of Mr. Thomas Taylor is less tedious than that specified by Professor Schönbein's representative; and, at the same time, a cotton quite as powerful is produced.

Dr. Ryan noticed, at an early period, that some specimens of cotton gave off, during explosion, considerable quantities of nitrous acid vapours. As this did not uniformly occur, he imagined that it might arise from the presence of small quantities of nitric acid, owing to imperfect washing; he therefore proposed, that before drying, the cotton should be rinsed in water containing a small proportion of ammonia. This was found to be a great improvement: Professor Schönbein, to the same end, employs a solution of carbonate of potass.

To increase the explosive character of the cotton, Dr. Ryan, also, was in the habit of employing a weak solution of chlorate of potass; but he found that cotton thus prepared was extremely dangerous, from the facility with which it exploded by friction, or percussion; he also noticed that it soiled and oxidated the gun barrel very rapidly. Professor Schönbein employs nitrate of potass for the same purpose, and more successfully, as it does not soil, or oxidate, so readily, the metal of the gun. Generally speaking, however, it is objectionable to employ any of the salts of potass, as they are liable to cause the production of smoke, or vapour, during explosion.

In the specification of Schönbein's patent, we are told that "the cotton in a damp state may be pressed into a mould, and afterwards made into cartridges." This, however, would never answer; for when the cotton is compressed, its explosion is often partial and uncertain. Thus, if a piece of cotton, four or five inches long, and half the thickness of the little finger, be laid on the table, and compressed in the centre by the edge of a card, or piece of sheet-glass, one end may be ignited, and yet the explosion will not go beyond the compressed part. So, also, under the influence of percussion, or sudden compression, we have often merely a partial explosion, a great portion of the cotton remaining untouched. In fact, we never have the *full* force of the cotton exerted, except the mass be light, and uncompressed. Thus in charging a pistol, for instance, a *pointed ramrod* is the best instrument to use.

Cotton, during its conversion into an explosive substance, increases very considerably in weight. Mr. Crum, F.R.S., in a Paper read before the Philosophical Society

of Glasgow, on the 4th of November, 1846, gave an account of a number of carefully performed experiments, for the purpose of ascertaining the increase of weight. He says, that in order to guard against error, from different states of dryness, before and after the experiments, as well as from loss of weight in washing, it was accompanied through all the operations by another equal portion immersed in the same quantity of acid, to which had been added just as much water as would prevent the cotton from becoming explosive. The difference in weight between the two portions was assumed as the real increase.

Four different mixtures were used.

I. Nitric acid of spec. grav. 1·5, with four-fifths of sulphuric acid, at 1·83.

II. Nitric acid of 1·48, with an equal volume of Nordhausen sulphuric acid of 1·86.

III. Nitric acid of 1·52, with an equal volume of Nordhausen sulphuric acid.

IV. Nitric acid of 1·43, with four-fifths of sulphuric acid of 1·83.

The increase upon 100 of cotton wool was in each of them as follows:—

I.	II.	III.	IV.
70·0.	67·2.	66·2.	64·7.

The increase in weight, during the preparation, is owing to the conversion of a great portion of the cotton into a new and distinct chemical compound.

Cotton, in its unprepared state, is nothing but *lignine*, a compound of the three elements, *carbon, oxygen*, and *hydrogen;* but after the action of nitric acid, we find another element present, namely, *nitrogen*—a substance entering into the composition of nearly all our explosive bodies.

The influence of nitric acid upon vegetable matter has long been known to practical chemists. The Author has himself seen an old manuscript recipe book, where, among other things, it was remarked, that "tow or cotton should never be employed to stop bottles containing materials giving off nitrous acid fumes, as sometimes an explosion was the result." This recipe book was nearly a century old. But although these things were in some measure familiar to the chemist, it was not until the year 1833 that any philosophical investigation of the cause, or nature of the action, took place. In that year, however, Braconnot, in a Paper published in the fifty-second volume of the 'Annales de Chimie et de Physique,' pp. 290–294, gave an account of a new substance, which he had obtained by the action of concentrated nitric acid on *starch, saw-dust, linen*, and *cotton wool.* To this new body, which he describes as being white, pulverulent, neutral, and very inflammable, he gave the name of 'Xyloïdine' (from ξύλον, wood.) This compound is easily formed by boiling starch, for a few moments, in concentrated nitric acid, until solution takes place. On pouring the solution into cold water, the xyloïdine is precipitated, and may be collected and dried.

Five years afterwards, Pelouze, in the 'Comptes Rendus' for 1838, again drew the attention of chemists to this remarkable substance; and after describing xyloïdine, he refers to experiments of his own, which anticipate, in a great measure, Schönbein's discovery. "Xyloïdine," observes M. Pelouze, "is very combustible, taking fire at 180° cent. (=356° Fahr.), and burning with great rapidity, and almost without residue.—This property has led me to an experiment which I think susceptible of some applications, especially in Artillery. By plunging paper in nitric acid of sp. gr. 1·5, leaving it there the requisite time for the acid to permeate the paper, which is usually accomplished in two or three minutes, then withdrawing it, and, lastly, washing it in water, we obtain a kind of parchment, impermeable to moisture, and extremely combustible."

This substance was investigated by several eminent chemists, and among others by Dumas, who notices it in the sixth volume of his 'Traité de Chimie appliquée aux

Arts,' p. 90, published in 1843. Dumas proposed to call the compound '*Nitramidine.*' He also mentions the application of paper, and pasteboard, prepared by nitric acid, for fire-works, (*pièces d'artifice.*)

We have already stated, that by boiling starch in nitric acid, solution occurs, from which solution xyloïdine is precipitated by water; so also, if instead of starch we employ *cotton*, we have a similar result; for if we pour the solution of *cotton* in *nitric acid* into a vessel of water, a precipitate is formed, precisely similar in external appearance to that obtained from the starch. This led chemists, for a long period of time, to take it for granted that *xyloïdine* was the product in both cases. Schönbein was the first to point out the contrary. He shews that there is some slight difference between the two precipitates, as one is soluble in acetic acid, while the other is not. It would perhaps be well, then, for the future, to give to the starch-product the name proposed by Dumas, namely, '*Nitramidine,*' indicating its probable composition; and to the precipitates from *cotton*, and other matters containing *lignine*, the term '*Xyloïdine,*' or '*Nitrolignine.*'

The explosive character, then, of gun cotton is owing to the formation of *xyloïdine*,* or *nitrolignine*, (distinguished from *nitramidine*,) in the tubes, and upon the exterior of the cotton fibre, under the action of the nitric acid. The sulphuric acid employed in the operation has no direct action upon the lignine; but is merely used to abstract the water of the nitric acid, and to render that substance more concentrated.

Gun cotton may be distinguished from common unprepared cotton, in the first place, by its *harshness*, and by the *crepitating sound* produced when pressed by the hand. When well prepared, there is scarcely any perceptible change in colour, or general appearance: some specimens are yellow, but that is the result of improper manipulation.

It may be distinguished from common cotton, also, in a moment, by its *electric condition*. This is a very important and satisfactory test. If a portion of the gun cotton be pulled briskly between the finger and thumb, taking care the hand is dry, the fibres of the cotton will adhere to the hand with great tenacity; and, if a strip of prepared paper be thus treated, it will, if one end be presented to the knuckle, strike it many times in succession, giving off its electricity.

Gun cotton may be distinguished also from common cotton by its perfect solubility in sulphuric ether. If the etherial solution be poured on the surface of cold water, the xyloïdine forms on the top of the water as an *opaque film*, resembling in texture and appearance the walls of a wasp's nest. This, when collected, and dried, forms a very remarkable and explosive paper.

The fulminating cotton explodes with very great rapidity, and at a much lower temperature than gunpowder,—the point of ignition being about 350° Fahr., or, according to some, at 400° Fahr. If a small heap of gunpowder be placed on a sheet of writing-paper, and a little gun cotton be laid lightly upon it, and the whole held about a foot above the flame of a lamp, or candle, the heat will in a short time be sufficient to ignite the cotton, while the powder will remain unkindled; and although the cotton explodes while in contact with the powder, yet its action is so rapid that it exerts no influence upon that substance. This great rapidity of action is opposed to its utility for propulsive purposes. It is well known to practical men, that a slowly exploding material is the best for Artillery† practice. Thus when a slow powder is used, the ball acquires a slight degree of motion, and puts the air in front of it in motion also, before the full power of the explosion is exerted; and that motion is gradually increased during the remainder of the explosion. But if the

* *Pyroxyline.*—See Appendix F.—*Editors.*

† See Appendices A. and B.

action takes place *too quickly*, the full force of the propelling power comes into play before the ball is in motion, and the bursting of the gun is the probable consequence. This is the reason why the fulminates of mercury and of silver have not been more extensively tried in warfare.

When gun cotton has been carefully prepared, the products of its combustion are *carbonic acid, watery vapour*, or *steam*, and *free nitrogen*. In some cases, as we before stated, nitrous acid is produced, owing to defective washing; and when nitrate of potash has been employed, or, in fact, a solution of any solid salts, a dense white vapour accompanies the explosion. The quantity of water produced during the decomposition of the cotton, by heat, is so great as to constitute an objection to its use in fire-arms.

Its hygrometric condition, also, impedes its utility; for if a quantity be exposed, for an hour or two, to a damp atmosphere, it absorbs nearly its own weight of water, and requires re-drying before it can be used: we have also stated before, that it cannot be protected from atmospheric moisture by compression into cartridges, as, in that state, it does not explode with certainty.

Dr. Ryan, at an early period of the discovery, pointed out that gun cotton might be so prepared as to give any coloured flame required; and in this way might be extremely useful for the construction of signal-lights, and also for the production of the usual pantomimic effects of our theatres. Thus, by using a solution of nitrate of strontia, before drying, the cotton would yield a red flame;—with chloride of copper, a green flame;—and blue, with nitrate of baryta. Paper, linen, calico, &c., may also be prepared in the same way; and when any of these materials are rolled up tightly, they may be made to burn a considerable length of time, and produce a very pleasing effect.

The idea of employing the fulminating cotton as a substitute for gunpowder,* for Artillery purposes, seems to be completely abandoned; but, on account of the small quantity of smoke given off, as well as on account of its enormous force, it is used much for mining† purposes; the proportionate quantity used being a fourth of that of powder. In the 'Athenæum' of October 24th, 1846, we have an account of the employment of cotton for mining purposes, given at the meeting of the Royal Geographical Society, the week before, at Penzance, by Mr. R. Taylor. In that account he remarked, that where cotton was employed in the proportion of one-fourth of the usual quantity of powder, not only was the earth broken up satisfactorily, but the miners were able to approach the spot immediately, and resume their work; while, if gunpowder had been employed, as the mine was not well situated for ventilation, at least three-quarters of an hour must have elapsed, before the smoke would have allowed them to work.

In conclusion, we may state that an attempt has been made to employ gun cotton as a motive power instead of steam; but up to this period no well-authenticated cases of success have been published.‡—J. R.

APPENDIX A.§

Report of a Select Committee held at Woolwich, 3rd *September*, 1846.

Dr. Schönbein attended the Committee and delivered in a Paper‖ detailing the proportions of his Explosive Cotton, and exhibited specimens of it in small quantities, prepared to different degrees of strength. He stated to the Committee, that he had verified the different properties which he ascribed to his preparation by many experi-

* See Appendix C. † See Appendices D. and E. ‡ See Appendix F.
§ By permission of the Master-General and Board of Ordnance. ‖ See Appendix.

ments, and proceeded to do so, in their presence, on a small scale. Some charges were introduced into a carbine, and exploded by the ordinary means of a percussion copper cap. They ignited readily, left the barrel perfectly clean, and appeared to have all the effects of gunpowder. A rifle loaded with the cotton, and the regulation belted ball, was discharged at a range of 80 yards, the effect and penetration of the ball being good.

From these trials, and from Dr. Schönbein's declaration, the Committee beg to report, that they consider the subject demands the fullest investigation, and they beg to recommend that Dr. Schönbein be applied to,* to furnish one hundred weight (1 cwt.) of his explosive cotton at the public expense, prepared in the strongest manner, which quantity would suffice to try the power and properties of the material on a moderate scale with muskets, rifles, and field-pieces. The Committee would report the result of the trials, with such recommendations as may arise out of them with regard to further experiments.

APPENDIX B.†

Properties of the Explosive Cotton, by C. F. Schönbein, Professor of Chemistry, 29th August, 1846.

1. It is more inflammable than gunpowder, but not yet ignited at a temperature of 400° Fahr.

2. It is not ignited by the friction or concussion occurring in charging cannon, mortars, rifles, or any other fire-arms, and mines.

3. Any means by which gunpowder is inflamed, also inflames the explosive cotton.

4. When prepared as strongly as possible, it does not produce any perceptible smoke or smell, nor leave any residue. A little less strongly prepared, it produces some smoke, but considerably less than gunpowder, and in this case the residue left is almost nothing; and fire-arms may be therefore discharged for any number of times without requiring cleaning.

5. The fire-arms are but little heated by using gun cotton, nor is their metal sensibly affected or corroded.

6. Water exerts no action upon strongly prepared gun cotton; for being dried again, it re-assumes all its primitive explosive force.

7. Gun cotton may be used in all cases where gunpowder is at present employed, without requiring any change in the fire-arms of the present construction.

8. From a great number of experiments made by Professor Schönbein, it appeared that in cannon and mortars, as well as in the rifles used in Switzerland, the propelling force of gun cotton is at least twice that of gunpowder, weight by weight. In America, with rifles of a certain construction, (narrow bores and conical balls,) the power of the explosive cotton is at least four times as great as that of the very best gunpowder. Similar results were obtained in blasting rocks and mines. With four ounces of explosive cotton, Professor Schönbein blasted, for instance, a very hard fragment of an old tower, of 250 cubic feet in size. To obtain the same result with gunpowder, at least two pounds of that article would have been made use of on the occasion.

9. The preparation of the explosive cotton does not expose to any danger of explosion, is most simple, and so quick that within 24 hours at most, the whole operation is gone through and finished. The arrangements for that preparation are equally of the most simple description, and little expensive.

10. The materials required for making gun cotton are cheap, easy to be had, and

* This was never supplied.

† By permission of the Master-General and Board of Ordnance.

there is every reason to admit that the same amount of propelling power produced by gun cotton will be sensibly cheaper than that obtained from gunpowder.

Note.—These statements have not been verified. The expense of gun cotton is considerably greater than gunpowder, and the application of the former for Artillery purposes has not been brought into use; and the quantity used in quarrying is limited. The subject of gun cotton and its component parts is not explained for the purpose of recommending its use, but by way of shewing when it may be adopted under peculiar circumstances, such as the want of gunpowder, or the impractibility of conveying it to the spot. And yet gun cotton could be manufactured, if the materials are available, whilst the mining operations are in progress; or, if manufactured at a distance, the extreme lightness of the article renders it easy of conveyance in bags, in any quantity, or slung on a pole upon men's shoulders, and thus transported with safety where neither horses nor carriages could pass.—*Editors.*

APPENDIX C.*

Results of comparative Experiments made with Pyroxyle, with Powder used for Small Arms and Artillery, with Powder as employed in Mines and the Extraction of Stones by blasting. Translated from the Report of the Commission to examine into the properties and powers of Pyroxyle as a projecting force.

1. In the spring of 1847, the above Commission, presided over by His Royal Highness the Duke de Montpensier, instituted at the Artillery Establishment at Vincennes, two series of experiments on military mines, employing pyroxyle, mining powder, and the powder used in small arms and artillery.

2. Shortly afterwards the Commission caused a number of experiments on the extraction of stones by blasting, using the same explosive compounds under the direction of M. Combes. The pyroxyle used in these experiments has been analysed by M. Pelouze. The experiments have led to the following results:

3. Pyroxyle placed in a barrel, and pressed with the hand, has a density which is only one-tenth that of powder; or more correctly, 0·084. In cartridges (dans les cartouches) this density can easily be doubled, that is, will be represented by 0·17 powder, being unity. If, after being placed in the barrel, some mechanical force be employed to reduce its volume, its density may be increased fourfold; or its value represented by 0·34. If the pressure be increased, the barrel breaks. With the last-named density (0·34) its explosive effects are as when pressed by the hand.

Composition of pyroxyle and powder; of their elements, and of the products of their combustion.

4. In order to facilitate the discussion of the relative powers of pyroxyle and powder (les propriétés des poudres et du pyroxyle), the atomical weight of the elements of each compound, as also of the products of their explosion (détonation),† are given in the annexed Table.

Comparative value of pyroxyle, powder used for small arms and artillery, and mining powder.

5. Let c represent the charge in gunpowder in a military mine, and c' a charge in pyroxyle: it has been found that when $c' = 0{\cdot}43\,c$, the radii of the craters produced by the explosions, and also the horizontal radii of rupture, are equal. Nevertheless, in the mine charged with pyroxyle, the solid of earth raised by the explosion was thrown upwards with less violence, and fell down again into the crater; and indeed it has been found to produce with pyroxyle an equal lined crater as with powder: c' must be increased to $0{\cdot}60\,c$.

6. This anomaly may be explained by stating that the vapour of water, which forms $\frac{8}{3}\frac{4}{2}$ of the products of the deflagration of pyroxyle, has at the moment of combustion a more expansive force than the permament gases, but that when the vapour or steam comes in contact with the earth, it is soon entirely condensed, and ceases to

* By Captain J. Williams, R. E.

† I think detonation here must be rendered combustion, or perhaps explosion.—J. W.

act; but, on the contrary, the products of the combustion of powder are permanent gases, not capable of condensation.*

7. The same anomaly is not remarked in the employment of pyroxyle in guns or small arms; because there is less surface in contact with the resulting gases, and the action is more instantaneous. In small arms, the co-efficient of pyroxyle to produce the same effect as gunpowder is about 0·35. In the blasting of rocks, the required co-efficient has been found to be 0·25 in relation to powder used for small arms and artillery, and 0·33 for mining powder; the strength of the former, compared with the latter, having been found to have the ratio of 0·33 to 0·25. The difference in expansive power in the two descriptions of powder may be explained by remarking, that the mining powder has less nitre, and therefore yields after combustion carbonic oxide and carbonic acid; and that the powder for small arms and artillery produces only carbonic acid. The carbonic oxide as a gas acts similarly in the explosion as carbonic acid, but having less heat, it has less elasticity.

8. The result of the above explanations points out that mining powder ought to be constituted similarly to powder for small arms and artillery; and that therefore nitrate of potash or nitrate of soda should be added, in order to upply the deficiency of oxygen. Experience has confirmed these suggestions of theory. By simply mixing 18 parts by weight of nitrate of soda, or 22 parts of nitrate of potash, to 100 parts of mining powder, M. Combes has made a gunpowder whose effects correspond exactly with the gunpowder employed for small arms and artillery.

New combustion of gases after an explosion of pyroxyle.

9. The products of the deflagration of pyroxyle contain carbonic oxide, and permit therefore of a new combustion of that oxide after the explosion. In experimenting with this view, M. Combes has succeeded in procuring this combustion; and this will explain the appearance of flame which is sometimes remarked after the explosion of mines charged with pyroxyle.

Amelioration of pyroxyle.

10. M. Combes concludes that it is always desirable to produce this second combustion after the ignition of the pyroxyle, by adding to the latter a compound that would supply it with oxygen. Experiments have confirmed M. Combes' opinions: it has been found that by adding to a kilogramme (2·206 lbs. English) of pyroxyle, 830 grammes (29·292 English ounces) of chlorate of potassa, or 818 grammes (28·868 English ounces) of nitrate of potash, or 690 grammes (23·645 ounces) of nitrate of potash, effects have been obtained equal at least to that of an equal weight of pyroxyle. The dipping of the pyroxyle into a solution of nitre has been found to be injurious. The salt encrusts the cotton, and prevents the access of the fire to it.

Suffocation produced by pyroxyle powder used in small arms & artillery, and mining powder.

11. From the investigations into the composition of confined air (de l'air confiné) by M. Felix le Blanc—'Annales de Chimie et de Physique,' tom. v. p. 245, line 3,—it has been shewn that a dog can live some time in an atmosphere composed of 70 parts of common air and 30 of carbonic acid; that in an atmosphere composed of 94 parts of air and 6 of carbonic acid, a candle will not burn; that persons in such an atmosphere breathe with difficulty, but run no danger from suffocation (d'asphixie); that an air vitiated by the combustion of carbon, and containing

19·19	oxygen,
75·62	nitrogen,
4·61	carbonic acid,
·54	carbonic oxide,
0·04	carburetted hydrogen,
100·00,	

and where candles burn well, has been fatal to a dog and a bird. The carbonic acid enters in the above analysis only in the proportion of 4½ per cent.; the carburetted

* Under ordinary pressure of the atmosphere.—*Editors.*

hydrogen is not a poison: of the other elements there is only the carbonic oxide which is so, and the above experiments shew how small a proportion is necessary to produce suffocation.

12. From the analysis given in the Table, it appears that the gases produced by mining powder and pyroxyle, containing a large quantity of carbonic oxide, must be considered as causing death by poison; and, under this view, the addition to this powder and to the pyroxyle of the nitrates, the presence of which corrects the carbonic oxide into carbonic acid, is strongly to be recommended, even if it did not augment the effects of the explosion.

13. But in considering suffocation as produced by the combustion of powder, there are other circumstances which it is important to inquire into.

In firing in a casemate, where the atmosphere soon becomes thick with smoke, and the sulphur and potash are observed on the dress of those present, there is much difficulty in breathing; yet under such circumstances there is no danger from suffocation. In the explosion, however, of a mine underground, where the gases evolved come in contact with the surface of the earth disturbed, it is often found that the miner, without any warning, dies from suffocation, while the candles still burn in the gallery.

Note.—I can, from personal experience, cite a very remarkable instance in illustration of the foregoing fact, which occurred in some extensive mining operations carried on at the Royal Engineer Establishment at Chatham in 1844.—J. W.

Remarks on the Use of the Comparative Table of Composition of Powder and Pyroxyle.

There are two modes of considering the chemical constitution of gaseous bodies, namely, first, by the atomical weight of their combining equivalents; and second, by the number of combining volumes. In the Table, each of these views is exhibited; but in order to take practical advantage of the column of relative volumes, some caution is necessary to those who may not be in the habit of using chemical formulæ. The column of volumes corresponds to the column of atomical weight, not to that of relative proportion per cent., and expresses therefore by volumes what the other expresses by weight: thus in the case of pyroxyle, $23\ CO = \overline{23 \times 175} = 4025$; but the combining volume of carbonic oxide is as compared to that of oxygen as 2 to 1, hence in volumes $23\ CO = \overline{23 \times 2} = 46$; 1 carbonic acid $CO^2 = 275$, but the combining volumes are 2, as in carbonic oxide; 5 nitrogen $= \overline{5 \times 175} = 875$, but the combining volumes are also 2, or $\overline{5 \times 2} = 10$: 17 vapour of water, or $17\ HO = 17 \times \overline{12{\cdot}5 + 100} = 1912{\cdot}5$, but in volumes, hydrogen and oxygen unite in equal quantities, so that the volumes are $17 \times \overline{1 + 1} = 34$.

If then the question arise, what is the comparative amount of volumes produced by the combustion of each description of explosive agent, the quantities given in the column of relative volumes must be reduced in the proportion of the gross atomical weight to the number 100, or to any other definite number representing the quantity used, and the Table thus reduced gives the following proportional quantities of gases produced by the combustion of an equal quantity of each material.

Poudre de guerre (for small arms and artillery) . .	·474 or 4·74
Poudre de mine (blasting powder)	·509 or 5·09
Pyroxyle	1·299 or 12·99

It must be also kept in mind that in this Table the French system of considering oxygen as 100 and hydrogen 12·5 is adopted; whereas hydrogen is frequently considered 1 and oxygen 8, or water $1 + 8 = 9$; but knowing this difference, a mere inspection of any representation of a chemical formula in atomic weights where oxygen, hydrogen, or water occurs, must shew which system has been adopted, and the corrections to be applied.

Table shewing the Composition of Powder and Pyroxyle, together with the Products of their Combustion.

POWDER.						PRODUCTS OF COMBUSTION.*				
Nature of Powder.	Atomical Composition.	Atomical Formulæ.	Atomical Weight.	Relative Proportion by weight, as deduced from Theory.	Relative Proportion by weight, as deduced from As adopted in Practice.	Nature of the Products.	Atomical Formulæ.	Atomical Weight.	Relative proportion per cent.	Volume (Rel.) of the Gases.
As used for small arms and artillery (de Guerre).	1 Nitre	$N O^5 K O$.	1264	75	75	Nitrogen	N.	175	10·36	2
	1 Sulphur	S.	200	11·85	12·5	Sulphuret of Potassium .	S K.	689	40·74	„
	3 Charcoal	3 C.	225	13·15	12·5	Carbonic Acid	$3 C O^2$.	825	48·90	6
			1689	100	100			1689	100	8
Poudre de mine, or blasting powder.	1 Nitre	$N O^5 K O$.	1264	64·40	62	Nitrogen	N.	175	8·9	2
	2 Sulphur	2 S.	400	20·35	20	Bisulphuret of Potassium	$S^2 K$.	889	45·2	„
	4 Charcoal . . .	4 C.	300	15·25	18	Carbonic Oxide . . .	2 C O.	350	17·8	4
						Carbonic Acid	$2 C O^2$.	550	28·1	4
			1964	100	100			1964	100	10
Pyroxyle.	2 Cotton	$2 (C^{12} H^{10} O^{10}.)$	4050·0	57·2	„	23 Carbonic Oxide . .	23 C O.	4025	56·7	46
	5 Nitric Acid (concentrated) monohydrate . . .	$5 (N O^5 H O$.	3937·5	55·5	„	1 Carbonic Acid . . .	$C O^2$.	275	3·78	2
			7987·5	112·7	„	5 Nitrogen	5 N.	875	12·72	10
	Deduct 8 Water . .	8 H O.	900·0	12·7	„	17 Vapour of Water . .	17 H O.	1912·5	26·8	34
			7087·5	100				7087·5	100	92
Powder when made with Nitrate of Soda.	1 Nitrate of Soda . .	$N O^5 Na O$.	1062	71·4	„	Nitrogen	N.	175	11·75	2
	1 Sulphur	S.	200	13·45	„	Sulphuret of Sodium . .	S Na.	487	32·80	„
	3 Charcoal	3 C.	225	15·15	„	Carbonic Acid	$3 C O^2$.	825	55·45	6
			1487	100	„			1487	100	

* *Detonation* in original.—J. W.

Table shewing the Composition of Powder and Pyroxyle, together with the Products of their Combustion—continued.

POWDER.						PRODUCTS OF COMBUSTION.				
Nature of Powder.	Atomical Composition.	Atomical Formulæ.	Atomical Weight.	Relative Proportion by weight, as deduced from Theory.	Relative Proportion by weight, as deduced from: As adopted in Practice.	Nature of the Products.	Atomical Formulæ.	Atomical Weight.	Relative proportion per cent.	Volume (Rel.) of the Gases.
Mining* Powder with Nitrate of Potash added.	Mining Powder . . .	$N O^5 K O + 2 S + 4 C.$	1964	100	,,	Nitrogen	$\frac{8}{6} N.$	233	11·9	$\frac{16}{6}$
	Nitrate of Potash . .	$\frac{2}{6} N O^5 K O.$	422	21·5	,,	Sulphuret of Potassium .	$\frac{4}{6} S K.$	460	23·4	
	(See paragraph 8.)					Bisulphuret of do. . .	$\frac{4}{6} S^2 K.$	593	30·2	
			2386	121·5		Carbonic Acid	$4 C O^2.$	1100	56	6
Idem.	Mining Powder . . .	$N O^5 K O + 2 S + 4 C.$	1964	100	,,			2386	121·5	
	Nitrate of Soda . . .	$\frac{2}{6} N O^5 Ka O.$	454	18·05						
			2418	118·05						
Pyroxile with Nitrate of Potash.	Pyroxyle	$C^{24} H^{17} C^{17} 5 N O^5.$	7087·5	100	,,	4·6 Carbonate of Potash .	$4{\cdot}6 C O^2 K O.$	3974·6	55·67	
	Nitrate of Potash . .	$4{\cdot}6 N O^5 K O.$	5814·4	82	,,	19·4 Carbonic Acid . .	$19{\cdot}4 C O^2.$	5335·0	75·6	38·8
	(See paragraph 10.)					9·6 Nitrogen	$9{\cdot}6 N.$	1680·0	23·75	19·2
						17 Vapour of Water . .	$17 H O.$	1912·3	26·95	34·0
			12901·9	182				12901·9	182	92
Do. with Nitrate of Soda.	Pyroxyle		7087·5	100·0	,,	4·6 Carbonate of Soda .	$4 C O^2 Na O.$	3045·2	42·9	
	Nitrate of Soda . . .	$4{\cdot}6 N O^5 Na O.$	4885·2	68·7	,,	19·4 Carbonic Acid . .	$19{\cdot}4 C O^2.$	5335·0	75·2	38·8
	(See paragraph 10.)					9·6 Nitrogen	$9{\cdot}6 N.$	1680·0	23·7	19·2
						17 Vapour of Water . .	$17 H O.$	1912·3	26·9	34
			11972·7	168·7				11972·5	168·7	92

* In the original—"complément de la poudre de mine."

Table shewing the Atomical Composition of the Substances which enter into the Fabrication of Powder and Pyroxyle.

Names.	Symbols.	Atomical Weight.	Rel. Volume of the Gases.	Names.	Symbols.	Atomical Weight.	Rel. Volume of the Gases.
Oxygen . . .	O.	100	1	Cotton . . .	$C^{12} H^{10} O^{10}$.	900	
Nitrogen . .	N.	175	2			1125	
Nitric Acid . .	$N O^5$.	675	„				
Hydrogen . .	H.	12·5	1			2025	
Water . . .	H O.	112·5	2	Potassium . .	K.	489	
Nitric Acid monohydrate	$N O^5 H O$.	785·5	„	Sodium . . .	N a.	287	
				Potash . . .	K O.	589	
Carbon . . .	C.	75	„	Soda	N a O.	387	
Carbonic Oxide	C O.	175	2	Nitrate of Potash	$N O^5$ K O.	1264	
„ Acid .	$C O^2$.	275	2	„ of Soda	$N O^5$ Na O.		
				Sulphur . . .	S.	200	

APPENDIX D.*

The following mines, charged with gun cotton, were exploded during the operations carried on at Bapaume during the Autumn of 1847.

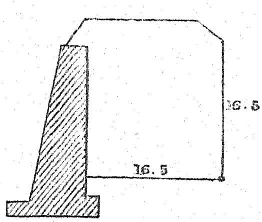
A charge of 29½ lbs. was placed behind the escarp of a ravelin, 4 feet 6 inches thick at top, and 9 feet 2 inches at bottom: the line of least resistance was 6·6 feet: the masonry was much shaken, but no practicable breach made, nor was the escarp thrown down.

In each instance of an experiment with gun cotton, a comparative mine was fired with gunpowder, with the view of ascertaining the relative force of the two compounds.

The equivalent experiment in powder to the above, consisted of a charge of 67 lbs., placed under similar conditions to the above. The explosion threw down the escarp, and formed a practicable breach, 25 yards wide. In assigning the ratio between gunpowder and gun cotton, so as to produce from the explosions an equivalent expansive force, the French Engineers had multiplied the charge of powder by decimal ·48: the result of the first experiment proved that this ratio was too high.

SECOND COMPARATIVE EXPERIMENT.

First with Powder.—Charge 293 lbs.: L. L. R. 16·5 feet: distance also from chamber to front of escarp, 16·5 feet. The mine was placed the last-named distance behind the escarp of a ravelin, which it overthrew, forming a crater about 34 feet in diameter.

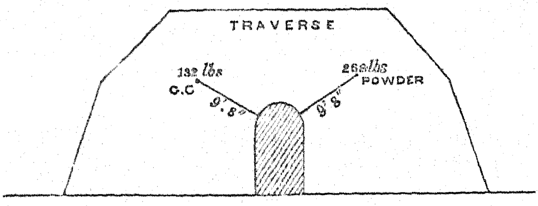


Same Experiment with Pyroxyle.—The factor ·48 having been shewn by Experiment No. 1, to have been too small, it was increased to ·6: the charge therefore was 293 × ·6 = 175·8 lbs. The explosion shewed the mine had been surcharged; not only by the more violent projection of fragments of the masonry, but by the form of the crater: the breach was quite practicable: the multiplier ·6 therefore gave a charge in excess.

* By Captain J. Williams, R.E.

THIRD COMPARATIVE EXPERIMENT.

First with Powder.—Charge 268 lbs.: L. L. R. 9·8 feet: the latter in the direction of a gallery which it was the object of the mine to destroy. About 3 feet of gallery blown in.



Co-efficient ·5. *The same Experiment with Gun Cotton.*—The conditions of the mine as above. The charge, however, was 132 lbs. The gallery was not injured from the explosion.

FOURTH COMPARATIVE EXPERIMENT.

Common mines situated under the terreplein of a ravelin.

First, Powder.—L. L. R. 13 feet: charge 205 lbs. The explosion produced a two-lined crater.

Co-efficient ·5. *Second, Gun Cotton.*—Charge 102 lbs. A similar crater was produced; the results of each explosion, as shewn by the crater, being equal. Decimal ·5 appears therefore the proper co-efficient.

A third experiment, under the above conditions of line of L. R., but adding 81 lbs. of nitrate of potash. No observable additional effect on the crater was produced by the addition.

Fourth Experiment. First with Powder.—This experiment consisted of a disposition of three mines placed behind the escarp of a face of a bastion. The extreme mines were loaded with 668 lbs. of powder; the centre one with 400 lbs. The line of least resistance was 16·5 feet: the escarp 15 feet thick at bottom, and 7 feet 6 inches at top. The extreme mines were placed at intervals apart equal to twice the L. L. R. A perfect breach was formed, 30 yards wide.

Parallel Experiment with Gun Cotton.—The disposition consisted of three mines, each charged with 335 lbs. of pyroxyle: the L. L. R. was 18 feet; otherwise the other details were as above. Only one mine exploded: it produced a breach 20 yards wide. The cause of the failure of the explosion of the other mines was fairly attributable to some disarrangement having taken place in the hose.

FIFTH COMPARATIVE EXPERIMENT.

First, Powder.—A charge of 80 lbs. behind the escarp of a ravelin, with a L.L.R. of 8 feet: it was contained in a powder-box whose volume was ten times as great as that occupied by the powder. The result of the explosion shook the revetment, but did not throw it over.

With Pyroxyle.—Charge 49 lbs.: circumstances of the mine as above, and the effects on the wall were about the same.

SIXTH EXPERIMENT.

Gun Cotton only.—Two charges of 400 lbs. each of gun cotton were exploded behind the escarp of a bastion, which was completely overthrown.

In addition to the above experiments, a small mine charged with gun cotton failed to ignite: probably from some disarrangement of the hose.

The gun cotton was placed in the chamber in bands, and fired by means of a hose invented by a Captain of Artillery, La Rivière, but very similar to our Bickford's fuze.

16th Oct. 1847. J. W.

From the results of the above experiments it appears, that when gun cotton is used in considerable quantities, that only one-half the equivalent weight of powder is necessary to produce the same result.

APPENDIX E.

DIRECTIONS FOR USING SCHÖNBEIN'S PATENT GUN COTTON, APPLICABLE FOR BLASTING EVERY DESCRIPTION OF ROCK AND MINERAL.

It is recommended that safety fuze should be used, and inserted into the cartridge to the extent of about two inches, and tied fast to the neck of the cartridge with a piece of string.

There is a black dot at one end of the cartridge, to shew where the fuze is to be inserted.

The hole to be tamped should be made sufficiently large in diameter, that the cartridge may reach the bottom without there being any occasion to force the same down.

The hole should be made as dry as possible before the cartridge is inserted.

When the cartridge is down to the bottom of the hole, put into the hole a handful of dry sand or clay, so as to cover the top of the cartridge to the depth of one or two inches; then proceed to ram or stem down, precisely as in the case of blasting with gunpowder.

The fuze being cut off to the required length, according to circumstances, all is ready for firing.

Where there is an absolute necessity for using the gun cotton in a loose state, a wood rammer only is to be used.

Note.—It appears that gun cotton has been partially used in the quarries of North Wales, where 8 ounces of gun cotton raised 60 tons of slates in two consecutive trials, and at a great variety of places this explosive compound has shewn its utility and enormous power. The patentees (Messrs. Hall and Co.) of Schönbein's gun cotton supply the article compressed in round and square paper cases of 4 oz. each, packed in boxes containing 50 and 100 cases.

It is considered by them that 4 oz. of gun cotton is equal to 24 oz. of blasting gunpowder.

Gun cotton is also made in tubes or

Cartridges of	1	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{1}{2}$
containing	2	4	6	8 oz. each.

For blasting in quarries, paper tubes are made 3 feet in length, containing one ounce of patent gun cotton per foot.—*Editors.*

APPENDIX F.*

ADDITIONAL REMARKS ON THE HISTORY, COMPOSITION, AND UTILITY OF GUN COTTON.

The preceding Papers, which contain some of the latest practical experiments on gun cotton, leave a doubt on the mind as to its general utility; and it is desirable therefore to look further at the subject. As a substitute for gunpowder in the

* By Lieut.-Col. Portlock, R.E. and F.R.S.

discharge of cannon, there is little chance that it should be ever rendered available; but that it may be so in the discharge of mines is extremely probable, and it ought to be considered an advantage to possess, especially in a large fortress, any additional means of defence. The mode of preparing gun cotton is very simple, and with proper attention and definite rules, may be rendered certain and safe; so that at any time in a well-provided Artillery Laboratory, it might on an emergency be prepared. The points to ascertain are, its real composition and the method of arriving at invariable results in its preparation. An uncertainty on this subject led chemists to confound the gun cotton of Schönbein with the xyloïdine of Braconnot, and Pelouze even, who claims to have suggested the preparation of combustible substances by the action of nitric acid on vegetable 'cellulose' (as in cotton, paper, wood, &c.), so far back as 1838, confounded it with the xyloïdine of Braconnot, which was the pulverulent amorphous matter thrown down in precipitating by water a cold nitrous-solution of starch, or a similar hot solution of 'cellulose.' As M. Pelouze is correct in his statement, he certainly preceded Schönbein in this discovery; but it must be admitted that the discrimination of the substance, and its separation from xyloïdine, were the results of the discovery of Schönbein, and that he may justly be considered its real practical inventor, as he arrived at it by peculiar theoretic considerations on the nature of hydrated nitric and sulphuric acids, the existence of which compounds he doubts. In Schönbein's theory, a mixture of 2 equivalents of sulphuric acid and 1 equivalent of nitric acid should be represented not as $2(S\,O_3 + H\,O) + N\,O_5 + H\,O$, but as $2(S\,O_2 + H\,O_2) + N\,O_4 + H\,O_2$, and that the result of the mixture would be to set free 3 equivalents of a binoxide of hydrogen $3\,H\,O_2$, which would act as a powerful oxidising substance. Whether this theory be admitted or not, it shews a very distinct line of reasoning which is quite original to Schönbein. Schönbein commenced his experiments on sugar, which, in the state of fine powder, he formed into a very fluid paste with a mixture of 1 part nitric acid of 1·5 sp. gr., and 2 parts of sulphuric acid of 1·85 sp. gr. at 36° Fahr., which, being well stirred, emitted no gaseous exhalation. The viscous mass was then separated from the acid, well washed with boiling water until free from acid, and deprived at a low temperature of as much of the water as possible. Exposed to a low temperature, the substance was compact and brittle; at a moderate temperature, it could be moulded like jalep resin, and assumed a beautiful silky lustre: it was semi-fluid at 212°; at higher temperatures it gave off red vapours; and when heated more, it deflagrated violently without leaving a perceptible residue. He then pursued his experiments on other organic substances, and made his principal discovery early in 1845 in respect to cotton, as well as in regard to those other substances described in the French Academy in Dec. 1845, and Jan. 1846. There can be little doubt, therefore, that but for this curious train of research, the former isolated discoveries of Pelouze and Braconnot would have remained without any practical result.

The latest English Paper on the subject, though several by Mr. Porrett and others had preceded it, is by Mr. John Hall Gladstone, of University College, London, and is published in the 'Philosophical Magazine,' Supplement, Dec. 1847. This writer first shews that well-carded cotton, perfectly white and free from impurities, is identical with lignine.

Cotton, as above analyzed by Mr. Gladstone.		Lignine, according to the Formula $C'_{24}\,H_{20}\,O_{20}$.	
Carbon . . .	44·37	Carbon . . .	44·44
Hydrogen . .	7·24	Hydrogen . .	6·17
Oxygen . . .	48·39	Oxygen . . .	49·39
	100·00		100·00

The excess of hydrogen in the first line is doubtless due to moisture absorbed in the operation.

The cotton was then steeped, until thoroughly wet, in a mixture of equal parts of nitric acid of sp. gr. 1·502, and strong sulphuric acid, then well washed with water, and dried at a temperature not exceeding 212°. In one instance 38·38 grs. became 66·84 grs., being an increase of 28·46 grs., or 74·15 per cent.: in a second, 59·3 grs. gave an increase of 43·7 grs., or 73·7 per cent. The gun cotton, or pyroxyline, thus produced resembled the original cotton in physical properties very closely, and exploded at about 370°, producing no smoke and leaving no residue.

As the increase of weight in making gun cotton has been differently stated by various authors, Mr. Gladstone tried first the effect of difference of time of immersion, but found no alteration. He then tried the effect of different proportions of the acids employed. With 1 measure of nitric and 2 of sulphuric acid, he found in three separate experiments increases of 56·84, 59·93, and 70·6 per cent., and endeavouring to account for the discrepancy, he first immersed the cotton in a large quantity of acid, and obtained an increase of 73·1 per cent.; and secondly in a small quantity, so as merely to wet it thoroughly, when the increase was only 51·74 per cent., and the acid residuum gave evidence of the presence of organic matter, which, in the case of a large increase, such as 74 per cent., it did not. The substance obtained was in each case true pyroxyline, and the diminution in quantity Mr. Gladstone ascribes to a partial destruction of the cotton by the sulphuric acid, when the quantity of nitric acid present is small,—a result which induces a caution as to perfect immersion, also recommended from other reasons by the French.

Adopting Dr. Schönbein's specified method, or using 1 part of nitric acid of sp. gr. 1·5, and 3 parts of sulphuric acid, the increase was 75·20 per cent. in one experiment, and 75·47 in another; so that the method has the advantage as to quantity obtained, and is preferable, as sulphuric acid is more readily attainable than such highly concentrated nitric acid. The identity of the substances, themselves, obtained in each mode was proved by analysis, and the true composition of pyroxyline ascertained to be —

$$\left.\begin{array}{ll}\text{Carbon} & 26{\cdot}23 \\ \text{Hydrogen} & 2{\cdot}73 \\ \text{Nitrogen} & 12{\cdot}75 \\ \text{Oxygen} & 58{\cdot}29\end{array}\right\}\ \text{represented by the formula } C_{24}\left\{\begin{array}{c}H_{15} \\ 5\,NO_4\end{array}\right\}O_{20}.$$

Xyloïdine was next obtained by treating starch with fuming nitric acid until the whole was converted into a gelatinous mass, and then precipitating by the addition of water the xyloïdine as a white powder, which was well washed and dried. This xyloïdine exploded at 360°, leaving a carbonaceous residue. When analyzed, it gave a proportion nearly corresponding to the formula (though the nitrogen was in excess) $C_{24}\left\{\begin{array}{c}H_{17} \\ 3\,NO_4\end{array}\right\}O_{20}$, in which the proportion of carbon to hydrogen would be 31·37 to 3·70, and not 26·23 to 2·73, as in pyroxyline; and it is this superfluity of carbon, which, as Schönbein observes, unfits it for an explosive agent. If nitric acid alone be used at sp. gr. 1·45, a substance different from pyroxyline is obtained, the formula of which is $C_{24}\left\{\begin{array}{c}H_{17} \\ 3\,NO_4\end{array}\right\}O_{20}$, or that of xyloïdine obtained from starch; and this same substance may be obtained by the action of nitric acid of 1·45 on pyroxyline itself. And further, if this product of the action of nitric acid on pyroxyline be again submitted to the action of the mixed acids, pyroxyline is reproduced.

Pyroxyline.	*Xyloïdine.*
Insoluble in pure water; nearly insoluble in alcohol, ether, and mixture of ether and $\frac{1}{10}$ of alcohol.*	Insoluble in water; slightly soluble in ether; more so in alcohol; and still more in ether with a small quantity of alcohol.*
Acetic ether destroys its fibre, and dissolves it rapidly.*	Dissolves in acetic ether.*
Dissolved by strong sulphuric acid only when aided by heat.*	Dissolved by sulphuric acid without heat.*
Not acted upon by fuming nitric acid.*	Soluble in fuming nitric acid.*
Dissolves in hot solution of potash.*	Dissolves in a boiling solution of potash.*

Gun cotton, or pyroxyline, is also dissolved with long boiling, by ammonia, the alkaline carbonates, hydrochloric acid, and weak sulphuric acid.

The characters above exhibited shew little difference between these two substances, and their close approximation is manifest from their respective formulæ; but it may be doubted, as stated by Mr. Gladstone, whether xyloïdine can always be considered a truly definite and fixed compound. Between that obtained from starch and that procured by Mr. Gladstone, from cotton, there is a difference in proportions, the starch xyloïdine giving carbon 24·0, nitrogen 3·42; and the cotton xyloïdine, carbon 24·0, nitrogen 2·65; but as both results approximate to the same chemical formula, they may be theoretically considered the same, or the 'coton hypoazotique' of M. Payen; though Mr. Gladstone from the circumstance of a different result, in acting on starch xyloïdine and on his new substance respectively by the mixed acids, proposes to retain the distinctive appellation cotton xyloïdine. Starch, when treated by the mixed acids, yields a substance of greater combustibility than xyloïdine, and still more closely resembling pyroxyline, yet distinct from it in some physical qualities; and this substance is also produced by the action of the mixed acids on xyloïdine, so that there is the same convertibility between xyloïdine—and what may be called starch pyroxyline—as between cotton xyloïdine and the true pyroxyline.

This difference of results between the action of nitric acid combined with *more than one equivalent* of water, and that when it is in the state of a mono-hydrate, or combined with one equivalent only, in the one case giving rise to products corresponding to the formula of xyloïdine, and in the other to products resembling pyroxyline, deserves especial attention, as any thing which tends in manipulation to place the nitric acid in the first state, or in combination with more than one atom of water, must lead to the formation of xyloïdine, and therefore be a failure: hence the use of even a much larger proportion of very weak sulphuric acid and a weak nitric acid will not be effectual in producing good gun cotton. To insure success, it is desirable to have a nitric acid of about 1·5 density, and this, mixed with either 1, 2, or 3 parts of strong sulphuric acid, will form an effective mixture.

The next most interesting substance of this class is the gun paper of Pelouze, which is formed by the action of the mixed acids on paper, either in its manufactured state, or in the state of dried paper pulp. It has been much tried in France, the paper being either rolled into the form of a ball or cut into shreds. In composition it is identical with gun cotton, or true pyroxyline, and, in short, every form of pure lignine may be expected to yield a similar result.

M. Pelouze estimates the cost of 100 kilogrammes of gun cotton, including manufacture, at about 370 francs, and 100 kilogrammes of gun paper at 150 francs, or, in English weights and money, gun cotton £7. 8*s.* 6¾*d.* per cwt., gun paper £3. 2*s.* 6*d.*

* These are results obtained by Mr. Gladstone.

per cwt.; but both from the early experiments by Mr. R. Taylor in Cornwall, made in presence of Schönbein, and from those of the French, the relative strength of gun cotton to that of powder may be stated as 4 to 1; and by Pelouze's statement, that of gun paper to powder, 3 to 1: hence the relative cost for comparison would be thus—quantity of gun cotton equivalent to 1 cwt. of powder . . . . } £1. 17*s.* 1½*d.* } Do. of gun paper } £1. 0*s.* 10*d.*
Both these substances, gun cotton and gun paper, have been tried successfully in fire-arms; but as the separation of the fibres of the former facilitates rapid combustion, it will probably be always found most suitable for that purpose; whilst in all those cases where it has been deemed desirable to condense the gun cotton, the gun paper made from paste or pulp will be found an equally advantageous and effective substance.

M. Pelouze has also tried to use his gun paper as a substitute for percussion caps; but though a loud detonation was heard, the matter was not perfectly consumed, and the fire was not regularly or with certainty communicated to the charge: but pyroxyline from any substance, used in a fibrous or shreddy condition, and placed in copper capsules, produced most powerful detonating caps; and gun cotton, mixed in capsules with a little common powder, was very effective.

The perfect combustion of pyroxyline is one of its most important qualities as regards fire-arms, but this is partially neutralized by the formation of much aqueous vapour. For mining it has this most important quality, that, after explosion, as in the case of the experiment made by Mr. Taylor at the Restomal iron mine, the mine may be immediately entered, whereas it must be inaccessible for a long time after the explosion of gunpowder.

Without, therefore, exaggerating the advantages of this remarkable compound, it must be considered most important to be able, on an emergency, to convert all the ligneous substances available, by an easy and not expensive process, into powerfully explosive compounds. In endeavouring, however, to do this, let it be first kept in mind, that whether the action of sulphuric acid be merely to remove the superfluous equivalents of water from the nitric acid, or, according to Schönbein, to co-operate in liberating the peroxyde of hydrogen, its presence is essential in at least an equal quantity to that of the nitric acid. 2ndly. That the cotton, paper, or other ligneous substance, should be fully immersed in the liquor, as the action of the air on the parts exposed may lead to the formation of an imperfect product. 3rdly. That great precaution is necessary in drying gun cotton, as the constant passage of air highly heated by contact with stoves, braziers, &c., may produce combustion, and, consequently, that no such stoves should be used in buildings where this material is prepared. The air heated by hot-water pipes (not on the high-pressure system) may be used with much safety.

In the field, the increase of bulk may counterbalance the diminution of weight; but it may be fairly suggested that in every great fortress provision should be made for rendering available, in time of need, the numerous substances, containing lignine, which are sure to be found in such circumstances.—J. E. P. Jan. 19th, 1848.

CONCLUSION.

Note on Gun Cotton by the Editors.—The perusal of the preceding pages on gun cotton will lead to the conclusion that there is no immediate prospect of its superseding gunpowder as an explosive compound, and it is possible other discoveries may render the application of gun cotton inexpedient.

The causes, as already explained, of the improbability of its being brought into general use, are—1. The difficulty of manufacturing gun cotton in large quantities, as the late disaster at Feversham shows; 2, and hence the great expense, (see

Appendix E.) Lastly, the danger, by friction, percussion, and even from moderate heat, under unaccountable circumstances.

These causes, after the novelty has worn out, will lead to the abandonment of gun cotton in quarrying, which, in fact, has already taken place, though perhaps in part from prejudices of the miners.

There is no question as to the power, and no secret in the manufacture of gun cotton, as explained in these Papers; but the adoption or application must rest in the judgment of the Engineer, in preference to or in the absence of gunpowder.

The discrepancy in the relative powers of gun cotton and gunpowder, as shewn in Appendix C., and as stated by the manufacturers, Messrs. Hall, of Feversham, in Kent, in Appendix E., may, independent of the relative purities of the substances used, be accounted for by the different circumstances under which they were tried.

In England, almost our only practical knowledge of the compound has been derived in quarrying rocks; and as the gases are in such cases closely pent up, and have no means of escape, the effect is powerful, and the result should approximate to the French co-efficient for small arms, viz. 0·35, or even to that for extracting stones, viz. 0·33, or 0·25 with the best powder. In the experiments the results of which are given in Appendix C., the gases mixed themselves with the soil, and the condensation of the vapour of water was facilitated, so that much of the moving force was annihilated; and this difference of result between blasting rocks and exploding a mine in earth had been also observed by Mr. R. Taylor in his early Cornish experiments. In earth mines, therefore, the charge of gun cotton must be one-half that of gunpowder, whilst in blasting or mining in rocks and old walls it may be reduced to one-quarter.

GUNNER,*—A term obviously derived from the word gun: one who is practically acquainted with the use of guns. In the improved state of modern artillery, to be master of the business of a gunner requires long and careful training and considerable experience. A gunner should be thoroughly acquainted with the powers and modes of serving the various descriptions of ordnance, whether guns, mortars, or howitzers, now in use, both for Field and Garrison Service. He must be acquainted with the nature of gunpowder, the mode of storeing and moving it, and the precautions necessary in all operations where powder or other explosive and highly inflammable preparations are employed. He should be able to make up ammunition of all kinds, and to prepare all pyrotechnical, commonly called laboratory, stores: the nature of solid (round) shot, cold or hot, hollow shot, grape, case-shot, spherical or common shells, carcasses, light-balls, and rockets, must be known to him, as well as the circumstances under which they are respectively best applied, whether his fire be direct, oblique, enfilading, vertical or ricochet, on land or water. He should readily appreciate distances over every variety of ground. The gunner must be conversant with the various modes of ~~investing~~ mounting and dismounting ordnance, and be familiar with the use of the engines, implements, &c., generally used in the Artillery Service. Although the British gunner, unlike Artillery of the military nations of the Continent, is not expected, as in the common course of his duty, to throw up batteries, lay platforms, &c., yet, as the exigencies of the Service may frequently call for the performance of such operations, where no adequate force of Sappers may be present, he ought to be instructed in those important branches of field-works. The French,

* By Captain Wilford, Royal Artillery.

Austrian, Prussian, and Russian gunner constructs his own battery, and then arms it; the British gunner should be capable of doing the same.

Enough has been said to shew that to form a really efficient gunner, an able-bodied, intelligent and well-instructed man is required.

While the gunner can dispense with none of the ordinary qualities of a good soldier, he has special need of the greatest steadiness and coolness in action: the efficient service of his gun requires the combined efforts of several men; his duties are altogether more complicated than those of the Infantry or Cavalry soldier, and if he act from impulse, or in a hurry, he will nullify the services of others, and render his gun useless. The heavy guns and stores the gunner has to deal with, the variety of labours and fatigues incidental to his branch of the Service, make, as the French say, "le goût de travail;" that is, a patien~~t~~ce and good-will in labour most essential to him. The gunner is further required to be versed in the use of small arms, and is liable to be called on to perform all the ordinary duties of the Infantry soldier. Since the close of the Wars of the French Revolution, the designation of simply 'gunner,' has ceased to exist in the British Artillery, except in the small portion of the Corps styled the Horse Brigade, known as the Royal Horse Artillery. The men of the ten Battalions of Royal Artillery are now called 'Gunners and Drivers,' and every gunner is as essentially a driver as a gunner, and is called upon indifferently to perform the duties of a gunner or a driver as may be required.

The duties of a driver, though not properly falling under the head of 'Gunner,' may be here glanced at.

The Artillery Driver must be able to drive all descriptions of horses and carriages, over every variety of ground. He must understand grooming, and the general care and treatment of his horse in all circumstances. In all field-battery drills and manœuvres much depends upon the intelligence and judgment of the driver, and, in action, the driver requires the highest degree of passive courage; he must sit quietly on his horse under the heaviest fire, ready to bring up his limber the instant ordered.

As the gunner and driver* has peculiar duties, so should he be imbued with a peculiar spirit proper to his vocation; and it were to be wished that his dress and equipments had a more distinctive character, and were more in harmony with his position as both a horse and foot soldier.

At present the cut of his clothes and general equipment are altogether those of the Infantry soldier, and, when mounted, his coatee, chaco, and Infantry great coat, convey the idea of a foot soldier mounted on some emergency, and not of one engaged in the performance of his proper and appropriate duties. The dress of the Artillery soldier should be soldier-like, but plain and useful, in keeping with the steady reflective character that ought to distinguish him.

Gunner, Garrison. A non-commissioned officer of Artillery, usually a serjeant, is appointed, in garrisons abroad, to act under the Adjutant of Artillery in all matters relating to the receipt and issues of ordnance, ammunition and stores, between the Storekeeper, the Commanding Officer of Artillery, and Officers in charge of artillery districts; in making out demands on the Storekeeper, returns for the Commander of the Forces, the Board of Ordnance and

* Pay of the Royal Artillery in 1848:

	s.	d.		
The pay of the Company Sergeant is	3	2	per diem.	The beer money is not included: one penny a day for all classes in Great Britain and Ireland.
Sergeant	2	8	,,	
Corporal	2	2	,,	
Bombardier	2	0	,,	
Gunners and Drivers	1	3¼	,,	
Trumpeters	1	3¼	,,	

The Sergeants have neither good-conduct stripes nor pay. All the others receive one penny a day in addition to their pay, for each good-conduct stripe they possess.—*Editors.*

Director-General of Artillery, in preparing salutes, and other occasional duties. The Garrison Gunner has charge of the flags of the garrison, which he hoists on proper occasions, as directed by the Commanding Officer of Artillery.

Gunner, Master. The appointment of Master-Gunner is an ancient office under the Crown. In the time of Henry VIII., Master-Gunners, with a certain number of gunners under them, are found on the establishments of the various forts and castles erected for the defence of the country. Master-Gunners were sworn to keep faithful charge of the ordnance and stores in their custody, and duly to instruct in their craft the gunners under their orders. Since the establishment of a Regular Corps of Artillery, the situation of Master would appear to have declined in importance. It is now filled by pensioned serjeants of Artillery, appointed, on the recommendation of the Deputy Adjutant-General, by warrant from the Master-General of the Ordnance. Their duties are to take charge of and render half-yearly Returns of all ordnance, carriages, powder, shot, and other stores and ~~habiliments~~ implements of war, appropriated for the use and defence of their respective forts and castles.

They are required, with the approbation and written authority of the Governor or Commanding Officer on the spot, to take charge of any ammunition or stores on the production of regular bills of lading or delivery, reporting the circumstance, and sending the authority in every instance to the Board of Ordnance.

They are directed to salute on certain Triumph Days, and to observe that 21 guns only, and those of the smallest nature, are to be fired: to acquaint the Governor or Officer commanding on the spot, and also the Officer of Artillery, before they fire on any occasion: to salute no person whatever without express orders from the Master-General, or Principal Officers of the Ordnance, except when Her Majesty or any of the Royal family are passing by. If the Governor or Officer in command on the spot, or the Officer * in command of the Artillery, should at any time require the Master-Gunner to expend any stores, or to salute on any occasion not provided for in the Instructions of the Master-General and Board of Ordnance, he is to request such order in writing, comply therewith, and represent the same to the Board.

He is to pay the greatest attention to the good order and preservation of the stores under his charge, that every thing may be in a state for immediate service. He is to take charge of the Invalid Artillery Detachment at the station where he is Master-Gunner, and to consider himself in every respect under the orders of the Officer of Artillery commanding in the district, and at the fort, garrison, or post where he is stationed, furnishing to such Officer any returns of ordnance and stores under his charge as he, the Officer, may require. Master-Gunners are amenable to military law, and subject to be tried by courts-martial.

Gunner, Quarter. This designation is usually applied to gunners of the Invalid Artillery, who are detached singly to different forts and castles, to assist and be specially under the orders of the Master-Gunners.

GUNNER, NAVAL.†

To qualify an individual to receive a gunner's warrant, he must have been at sea at least seven years, one complete year of which as Gunner's Mate, or other *petty officer* or seaman-gunner in Her Majesty's Navy; and he must produce certificates of his servitude and good conduct; and pass such *examination* as the Admiralty may from time to time direct: but no *candidate* shall be examined before he shall have attained the age of 21 years, nor after the age of 35.

* The Master-Gunner is likewise under the orders of the Officer of Artillery commanding the district, fort, garrison, or post.

† Queen's Regulations for the Naval Service, 1844.

*The Examination of Naval Gunner** to ~~consist of~~ prove his being in all respects a good practical seaman; that he knows the use and service of the *great guns;* that he knows the proportion of powder for guns of every description, filling cartridges, and the arrangement in the magazine, *shells* and *fuzes*, and how to fill musket cartridges; that he can write sufficiently well, and understands the use of figures.

Relative Rank and Command of a Gunner † in Her Majesty's Navy is first on the list of Warrant Officers, and next to that of Officer, and follows that of Master's Mate in assuming the command of a ship.

Gunner's Mate stands fourth in the list of petty officers in Her Majesty's Navy, and must be confirmed on examination in gunnery on board the *Excellent.**

Gunners, Seamen, are instructed in the theory and practice of gunnery and great-gun exercise after having been entered in Her Majesty's Service for five years—they are qualified on board the *Excellent,* and are borne on the books of Her Majesty's ships as *Seamen Gunners,* for which they have additional pay.

GUNNERY,‡—The art of using fire-arms; but the term is commonly understood as being restricted to the use, or application to the purposes of war, of the larger pieces of ordnance, as cannon, mortars, and howitzers. In its practical branch, Gunnery includes a just knowledge of the construction of the several pieces of artillery, and of the strength, tenacity, and resisting power of the materials of which they are formed; of the method of mounting them upon strong, efficient, well-proportioned and conveniently constructed carriages; of the proportions due to the strength of the powder and projectiles they should carry; of the force and effect, and also of the manufacture of gunpowder; and, generally, of all such mechanical arrangements and appliances as may facilitate the movements and working of the guns, &c., when prepared for action. But Gunnery takes a yet far more extensive range; for it may be said to be based upon nearly every branch of the mathematical and physical sciences, and may be itself considered as a science requiring the most intricate combinations of human knowledge and mechanical ingenuity fully to comprehend and perfect. It particularly requires an acquaintance with all experiments which may have been made to ascertain the impetus of projection, the momentum of bodies in motion, and the range and time of flight of projectiles with given charges of gunpowder,—with the effect of the resistance of the atmosphere upon projectiles propelled with different velocities, and the laws of gravitation as affecting falling bodies; and with the various causes, mechanical and otherwise, of the usual deflection of projectiles in their course, when fired from a gun.

Upon the practical portion of the art, but little need here be written; for so various are the subjects which would require notice, that to treat of each in detail, a mass of matter must of necessity be given which would occupy more space than could be allowed in a work of this nature; and, for the like reason, it would be still less possible to be discursive upon all those points of philosophy which are embraced within the vastly extended circle of the Science of Gunnery. Some observations, however, upon what may be deemed its history, or the progress it has made up to the present time, may not inaptly here be given.

Previous to the invention of gunpowder, machines for throwing stones, spears, arrows, and burning materials, were in use for the attack and defence of towns, fortresses, and ships; and these, which had at an early period assumed the name

* Admiralty Instructions, 1844. † Queen's Regulations for the Naval Service, 1844.
‡ By Lieut.-Colonel Dundas, C.B., Royal Artillery.

of Artillery, so continued until the thirteenth century, though the smaller pieces of artillery, cross and long bows, were retained for the purposes of war, long afterwards. All those implements, however, gave place to hollow * cylinders of wrought iron, of clumsy and inconvenient form and structure, without trunnions, and made to load at the breech, from which, at first, masses of small stones and balls of the same material of, in many cases, prodigious weight, were thrown by means of very imperfect and weak gunpowder, which was long used in the ungrained state. And these latter, in their turn, gave place to the more modern cannon cast in bronze and iron, lighter, and much more easily manageable, from which iron balls of smaller size and weight, but with infinitely greater velocity and correctness, were thrown.

Gunpowder was, as before noticed, first employed in the ungranulated state; but when the danger, inconvenience, and loss of power arising from its being used in that condition became apparent, it was brought into the form of grains, at first, from the difficulty and slowness of the operation, and the comparatively small quantities so manufactured, to be used with small arms only; and after an interval of many years, when the process of granulating was rendered more easy and expeditious by improved mechanical arrangements, for the general purposes of artillery.

Long after the invention of gunpowder, Gunnery appears to have been considered as a mere practical operation, to which the small amount of general science then existing was in no way directed; nor does it appear that it excited the attention of philosophers until Nicholas Tartaglia, an Italian who lived in the sixteenth century, attempted to bring science to the aid of the art; though little advantage was derived from his labours and those of other philosophers of that period, from the general crudeness and incorrectness of their ideas on the motion of projectiles, and the circumstance of the theories formed by them never having been brought to the test of experiment. But the masculine and original mind of Galileo enabled him firmly to grasp the subject, and he it was who first attempted to resolve it into a science. He applied to Gunnery those laws observed by nature in the production and composition of motion, and was the first who correctly described the effect of gravity on falling bodies, or the tendency of ponderous masses of matter to descend to the earth from a place of rest above its surface; and on those principles he shewed that the course of a cannon-ball fired from a gun would be in the curve of a parabola, unless it should be diverted therefrom by the resistance offered to it by the atmosphere; but he was unable to determine by experiment the amount of that resistance, and he left to those who might follow him the solution of that most important problem.

From the time of Galileo to that of Newton, the hints thrown out by the former as to the probable retardation of a projectile from atmospheric resistance were neglected, or rather were wholly overlooked; and without farther question or consideration, it was generally assumed that such resistance would produce no great effect, as the extreme rarity of the air would be as nothing when compared with the ponderous masses of shot in projection; and without attempting any experiment to prove the correctness of their views, disregarding wholly the expressed opinion of Galileo, they deemed it an established maxim that the course of projectiles was very nearly in the curve of a parabola, and that any departure therefrom was too trifling and insignificant to be attended to in calculation.

* The first fire-arms used in the field were made to load from the chamber, and this arrangement was extended, as stated in the text, to large cannon; but either anterior to or coeval with the cylindrical cannon was the ancient bombarb of a conical form, from which were projected large stone shot. The term bombarb is very ancient, having been used anterior to the application of gunpowder to projectiles.—*Editors.*

The master mind of Newton, however, readily detected and dispersed the errors of those who preceded him: he shewed that in the usual high velocities of military projectiles, the resistance of the air increases nearly as the squares of their velocities, and proved that the track of projectiles passing through the air with swift motions varied greatly from the parabola.

After Newton's time, nothing farther was done towards the establishment of a just Theory of Projectiles until our countryman, Benjamin Robins, demonstrated clearly that the resistance of the air to bodies moving in it, is much greater than Galileo imagined, and that it could not be neglected as an opposing power in Gunnery; and he gives three different cases of resistance in an uniform medium.

1st. When it resists in the ratio of the velocity.

2ndly. When it resists in the duplicate ratio, or as the square of the velocity.

3rdly. When it resists partly in the ratio and partly in the duplicate ratio of the velocity.

The second case, however, agreeing more nearly to that which takes place with military projectiles, is alone considered in calculations in Gunnery; and he farther determines the proportion between the times of ascent and descent of bodies; but it is to be regretted that he did not ascertain the path which a body would describe under the influence of the two motions. After Newton, the labours of Bernouilli were directed to the same point, but with the like result, as the only knowledge we derive from them is, that all rules which can be applied are insufficient, and that the ever-varying force of resistance prevents our obtaining an exact solution of the important problem.

In the year 1742, Mr. Benjamin Robins, who had early applied himself to making experiments in Gunnery, which were conducted with much patience, labour, and ingenuity, published his work entitled 'New Principles of Gunnery,' wherein he treated not only of the resistance of the atmosphere, but likewise of the force of gunpowder, and of the effects of guns of different lengths and weights, and of almost every other thing which in any way related to the motion of projectiles, carrying the Theory of Gunnery which he established upon the results of carefully conducted experiments nearly to its utmost perfection. He shewed, or perhaps rather attempted to prove, that the great effect of gunpowder was due to the disengagement of a highly elastic fluid in a greatly condensed state in gunpowder, which, on combustion, became liberated, and expanding with amazing quickness and force, violently impelled balls and other matter opposed to it. Having, as he supposed, determined the propelling force of gunpowder, he proceeded to the determination of the effects it will produce upon, or the velocity with which it will propel, a projectile from a gun.

We will here give Robins' own account of the machine by which he measured the velocities of balls, which is simply a pendulous block of wood suspended freely by a horizontal axis, against the end of which were fired the balls whose velocities he determined "to such a degree of exactness (which may be augmented too, at pleasure) that in a bullet moving with a velocity of 1700 feet in a second, the error in the estimation of it need never amount to its 500th part, and this without any extraordinary nicety in the construction of the machine."

With this instrument, "if the weight of the projectile be known, and likewise the respective distances of its centre of gravity and its centre of oscillation from its axis of suspension, it will thence be known what motion will be communicated to this pendulum by the percussion of a body of known weight moving with a known degree of velocity, and striking it at a given point; that is, if the pendulum be supposed at rest before the percussion, it will be known what vibration it ought to make in consequence of such a determined blow; and, on the contrary, if the pendulum,

being at rest, is struck by a body of a known weight, and the vibration which the pendulum makes after the blow is known, the velocity of the striking body may thence be determined: hence, then, if a bullet of a known weight strike the pendulum, and the vibration which the pendulum makes in consequence of the stroke be ascertained, the velocity with which the ball moved is thence to be known:" the rules for the calculation of which may be seen in the works of Robins, Euler, Antoni, and Hutton, to which we refer our readers.

By the machine described, Robins made many experiments from which he arrived at most important conclusions; indeed, by its means he determined nearly every thing relating to the true Theory of Projectiles and the Practice of Artillery.

It may be well here to note that the material fired at, a block of wood, was subject to much destruction from being used, and required compensation to be given for the addition to its weight by the shot or parts of shot which remained in it, and the pieces or wedges of wood which required to be driven into the centre of the block to produce a fair surface to receive the succeeding shot; but in consequence of the inconvenience and delay arising from the described operation, of late years cones of gun-metal have been used, which, after every shot, are re-filled with sand, brought to a certain degree of dryness and weight, and, in order that it may be more effectually retained, covered over with a thin plate of lead. This arrangement, for which, as we understand, we are indebted to Piobert, an Officer of Artillery of much celebrity and distinction in France, would probably be adopted by us in England in the event of any experiments with the Balistic pendulum being required to be carried on.

To the learned and very valuable commentaries of Euler upon Robins' publication, the science of Gunnery is greatly indebted; for independently of the original views taken of the subject, the new theory was brought thereby more generally to the notice of the scientific world, and greatly enlarged upon, omissions being supplied and corrections added where considered necessary. Euler also attempted the investigation of the nature of the curves of projectiles, and formed Tables for the solution of all cases which occur in Gunnery, but unfortunately the calculations resulting from his theories have but little accordance with practical results. Indeed, his description of the curve in which a projectile moves is so extremely perplexed, that no deduction, upon either philosophical or mechanical principles, can be made from it.

The laws and deductions made from the Balistic experiments by Robins and Hutton, with which all artillerymen should be acquainted, are considered as little necessary by the mere practical man, who, with Tables of Ranges is, it must be admitted, able to perform with effect all ordinary service that may be required of him; but a just knowledge of the principles of the science of Gunnery is nevertheless indispensable; for without such knowledge, important points of construction and laws and deductions obtained from practice are lost sight of.

We have endeavoured, in the former part of this Paper, to shew how various are the subjects of a scientific nature which have reference to Gunnery; and, without attempting any lengthened elucidation, we shall be satisfied in giving a brief digest of what may be considered as absolutely necessary to be held in remembrance by the practical Artilleryman.

I. THE PROPERTIES OF MATTER TO BE CONSIDERED IN REFERENCE TO GUNNERY.

Inertia is that property of matter by which it will remain at rest until put into motion by the application of force; or, being in motion, will continue in motion until stopped by an opposing force.

Gravity is the tendency of all bodies towards the centre of the earth. The force

of gravity is in the inverse proportion to the square of its distance from the centre of the earth.

Weights of Bodies are as their quantities of matter.

Specific Gravity of Bodies is their comparative weights under equal bulk.

Density of Bodies is the greater or less quantity of matter contained in the same bulk. In common parlance, bodies are said to be more or less heavy when their density is greater or less.

II. MOVEMENT OF BODIES.

Momentum of a Body is the product of its velocity and weight.

Velocity of a Ball is the measure of its flight, and is estimated by the rate per second at which it passes through the air.

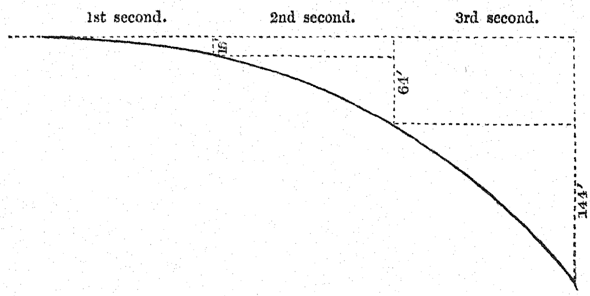
Its *Initial Velocity* is the rate at which it quits the muzzle of the gun; but this can only be practically ascertained when it has arrived at a certain short distance from the gun.

Its *Remaining Velocity* is its velocity when it strikes the object aimed at.

It is impossible to ascertain velocities with perfect exactness; but as the science of Gunnery requires that those points should be ascertained as nearly as possible, it had long been the object of philosophers to determine them, or to make as near an approximation as possible to the truth; and, as we have before shewn, the very original contrivance of the Balistic pendulum by Robins has removed many of the difficulties which stood in the way of perfect success in this matter.

III. THE PARABOLIC THEORY.

A projectile in free space having been impelled by a charge of gunpowder from a piece of ordnance, will continue to move in the direction in which it was impelled through equal spaces in equal times, being continually drawn by gravity towards the earth: but the projectile will fall precisely in the same time that a similar body would if let fall from a place of rest; and, while the force with which it was impelled is operating in the direction in which the piece was laid, it continues to fall by the action of gravity through spaces proportioned to the squares of the times. Bodies fall through 16 feet nearly in the first second of time; and, as before said, the spaces being as the squares of the times, that passed through at the end of the second second will be 64 feet; at the end of the third, 144 feet; and at the end of the fourth, 256 feet. See the following diagram in explanation.



The properties of the parabolic curve being known, it was supposed to be easy to calculate the flights or ranges of projectiles, but practice disagrees most widely with the theory, for the atmospheric resistance is continually retarding the projectile; and the parabolic theory, however beautiful in itself, is practically inapplicable in Gunnery,

and is only useful in demonstrating, by comparison with results in practice, the quantum of atmospheric resistance.

IV. LAWS AND RULES OF GUNNERY DEDUCED FROM EXPERIMENT AND PRACTICE.

The atmosphere presses alike upon any body at rest equally and in every direction: if a ball move with any great velocity through the air, the air in front is condensed, and it is rarefied or forms a partial vacuum behind; hence, not being in equilibrio, being pressed upon from before, it meets with retardation in proportion to the square of its velocity; and not until the velocity is reduced to about 1400 feet per second does the displaced air return freely to fill the vacuum; but 1600 feet is the maximum velocity that should be given to a projectile, and that or any greater velocity is supposed to be reduced to about 1400 in passing over about 400 feet of space.

By the Parabolic Theory, greater or less bodies of equal densities, propelled with equal velocities and elevations, have equal ranges; but in practice it is not so: the retardation of small is greater than of larger bodies, because the resistance being upon the surfaces, is as the extent of those surfaces, which is as the squares of their diameters; whilst their power to overcome resistance is as their weights or the cubes of their diameters: hence the force to overcome atmospheric resistance increases faster than the resistance increases, and the larger is less opposed than the smaller ball. It is obvious that balls of greater density are less retarded than those of less density of the same diameter; for their surfaces being equal, the resistance to them is so likewise; but the power to overcome the resistance is greater in the denser body, and its retardation is therefore less.

Solid shot, propelled with equal velocities and elevations, range according to their weights; that is, the heavier ball will have the greatest range: hence solid shot outrange hollow shot when of the like diameter, because of the inequality of their weights.

Shot of equal weights and diameters, propelled with different velocities, will range according to their velocities, but not in direct proportion thereto, for the retarding power varies as the squares of the velocities.

V.

Velocities of shot increase with the charges in the ratio of the square root of the charge to a certain point, but diminish with largely disproportioned charges.

Velocities of shot from guns of equal weight with equal charges increase in a ratio between the square and cube roots of their length to a certain limitation of length.

Velocities of shot of the same diameter, but of different weights, are inversely as the square root of the weights.

Penetrations of shot of equal diameter are as the square root of the charges.

A law has been deduced from experiment, shewing that the accuracy of balls, or the probability of their hitting at distant ranges, is as the squares of their diameters.

At 1000 yards	the 68-pounder	should strike	$15\frac{1}{2}$	times.
„	42 „	„	11	„
„	32 „	„	$9\frac{1}{2}$	„
„	24 „	„	6	nearly.
„	12 „	„	5	times.
„	9 „	„	4	„
„	6 „	„	3	nearly.

By Dr. Hutton's rule for ascertaining the remaining velocities of shot, we have for the 32-pounder, with an initial velocity of 1600 feet per second, at 500 yards from the gun, 1126; at 1000 yards, 815; at 1500 yards, 608; at 2000 yards, 465; and at

2500 yards, 367: with these as data, we have an easy means of ascertaining the remaining velocities of other natures of ordnance.

VI.

As a general law of nature, action and re-action are equal, and in contrary directions. In Gunnery, the charge of gunpowder on expansion acts upon the gun and shot with equal power, of which the Recoil of the one and the Range of the other are familiar examples.—But to explain, the elastic fluid generated on combustion is re-acted upon by the shot, and the gun is forced to recoil with considerable momentum; but with a gun light in proportion to the weight of its projectile, the velocity of its recoil increases, and is violent in proportion to its lightness.

The momentum of a gun in its recoil is of easy calculation, momentum being the product of weight into velocity.

The common charge of a 24-pounder gun of one-third the weight of its shot gives, say 1600 feet per second of initial velocity:

$$1600 \times 24 = 38{,}400, \text{ the momentum of gun and shot;}$$

$$\frac{38{,}400}{5600}, \text{ or } \frac{\text{momentum by}}{\text{weight of gun in pounds,}} = 7 \text{ feet per second nearly:}$$

with a lighter gun of 3580 ℔s., the velocity of recoil will be $10\frac{1}{2}$ feet per second.

These calculations are made without reference to the weight of the carriage, which should be added to that of the gun in all calculations for recoil.*

GUNPOWDER.†—Probably no invention ever produced so great a change in warfare as the combination of the ingredients of which Gunpowder is composed. It is the agent upon which Modern Military Tactic is based: its projective power determines the arena of battle, as well as the length of all Lines of Defence whether for musketry or artillery; and it consequently regulates the construction of Collateral Defence. It is brought into use by every arm, as well in Attack as Defence, for the musket, the cannon, and the mine.

The following sketch of the elements and manufacture of this powerful agent may therefore be interesting, although the full detail would involve a treatise beyond the limits or object of the present work.

The component parts of gunpowder are *saltpetre*, *sulphur*, and *charcoal;* and the proportions of those ingredients used in the manufacture of every 100 ℔s. of gunpowder are—

Saltpetre	$77\frac{1}{2}$ ℔s.
Sulphur	$10\frac{1}{2}$
Charcoal	16
the extra 4 ℔s. being allowed for waste.	104 ℔s.

The atomic composition which approaches nearest to that of gunpowder is 1 equivalent of nitre, 1 of sulphur, and 3 of carbon, or

Saltpetre	74·6
Sulphur	11·9
Charcoal	13·5
	100·0

and this is very closely adhered to in some foreign gunpowders.

* It may be here observed, that the vis viva of the expanded charge is directly communicated to the gun, which should be of sufficient weight to sustain it without detriment to the carriage, which will be great in proportion to the lightness of the gun.—W. D.

† By Major-General Fanshawe, R. E.

Saltpetre is never found in a pure state, and is imported in its impure state, called grough saltpetre: it is totally unfit for gunpowder until it be purified, as in its grough state it is combined with salts which greedily absorb moisture, and which would derange the close contact and combination of the above ingredients. The purity of saltpetre is therefore an important consideration in the manufacture of good gunpowder; and it is more or less refined according to the care of the manufacturer, or the quality of the gunpowder required. When properly freed from impurities, it loses $\frac{8}{100}$ of its weight in the process.

The process of refining is by solution in an equal weight of spring or river water, which is raised quickly to a boiling heat, and, after four or five hours, allowed to cool; when it is filtered through canvass bags, previous to being poured into copper pans for crystallization. A second purification is necessary, precisely similar to the first, but with a reduced proportion of water, the nitre being to the water as 14 : 10; after which all remaining water is expelled by fusion; and the crystallized nitre will have a delicate white appearance.

The principle of this purification is founded on the greater solubility of nitre in hot than in cold water: 100 parts of water dissolve 236 parts at 207°, and only 29 at 64°; whereas nitrate of lime is a deliquescent salt, and therefore retained in the menstruum after the crystallization of the nitre.

Sulphur is purified sufficiently for gunpowder, simply by a double process of fusion in gun-metal pots by gentle heat for about four hours; and it loses $\frac{1}{10}$ in the refining.

Charcoal is the woody fibre that remains after the liquid and more volatile parts of the wood have been educted by fire in the process of charring, which process is now usually conducted in iron cylinders instead of in charcoal pits, as formerly, as the charcoal thus produced is found to be less contaminated with foreign mixtures: the wood, when properly charred, loses about $\frac{5}{7}$ of its weight: the liquid products which are drawn off are coal tar and pyroligneous acid.

The most valuable woods for charcoal are the black dog-wood, the alder, and the Dutch white willow.

Charcoal is best for gunpowder when newly made from seasoned wood: its goodness is an essential point in the quality of gunpowder: it should be perfectly charred, exhibiting throughout its section the same appearance, either dead black, or shining, according to the nature of the wood; quite soft, and free from extraneous particles, so as not to scratch polished metal: when in combustion, it should give out no smoke; and, when tested in boiling distilled water, should exhibit no alkali. It is also to be observed that charcoal, if stored, or intended for transport, should be separated in small quantities of 2 or 3 cwt., as it has been ascertained that when subject to friction, or the pressure of a large quantity in a mass, spontaneous combustion takes place.

For the manipulation of gunpowder, the above ingredients are reduced to the fineness of impalpable powder, and the proportions above given merely mixed together in a tub or small barrel before being placed in the incorporating cylinder mill, in charges of 42lbs. each, moistened by 2 or 3 pints of water, as the temperature, or the humidity of the atmosphere, may influence it. In new work, each charge requires to be $3\frac{1}{2}$ hours in process of incorporation; and this period consequently regulates the quantity of gunpowder which can be manufactured by one incorporating mill. But it is much to be considered whether by a greater degree of manipulation in the mixing tub, a shorter time for each charge would not suffice under the cylinders of the incorporating mill, and thus produce, without compromising the thoroughly close and compact combination of the elementary particles, a much greater quantity of gunpowder in a given time.

The mills may be worked by any description of power, provided the speed be duly regulated; but the cylinders or runners cannot safely be made to revolve more than eight times per minute. Formerly, the runners and beds were ordinarily of compact limestone or marble; but cast iron is now used with safety, provided the gudgeons work in gun-metal. The runners or cylinders are 6 feet in diameter, and about 18 inches thick, and should weigh about 3 tons each. The circular bed in which they travel is about 7 feet in diameter.

The thorough incorporation and combination of the elementary parts of the ingredients are most essential in good gunpowder. The operation is one of tact, and requires experience to judge of its sufficiency, the practical indication of which is a uniform greyness of appearance, and a liveliness of the composition during the latter part of the process.

The incorporated material is termed mill-cake, and is then subjected to a pressure of about 75 tons per superficial foot, in Bramah's hydrostatic press, or by a powerful mechanical power, by which it is brought into a much harder substance, called press-cake; after which it is crushed between toothed rollers of different successive gauges, or broken by wooden mallets into small pieces, which are put into parchment sieves in a frame suspended at the corners, to which a shaking motion is given. Each sieve has in it two pieces of lignum-vitæ, which, by the motion given to the frame, continue to crush the powder until it be of a size to pass through the holes which are pierced in the parchment, of the size required for the gunpowder, into hair-cloth sieves, which retain the grained powder, and allow the dust to pass through.

The gunpowder is then glazed, *i. e.* placed for 1½ hours in a canvass cylinder or a large cask, which is made to perform about 40 revolutions per minute, by which process of abrasion of the grains the angular points are broken off, and the grains acquire roundness as well as smoothness and polish of surface.

The operations of pressing and glazing do not impart strength or propelling force to the gunpowder, but give an equal degree of density to the grains and a polish to their surface, which render the gunpowder less susceptible of absorbing moisture and more competent to withstand the shaking and friction of carriage.

The next operation in the manufacture of gunpowder is the drying it thoroughly by a degree of heat of not less than 140° or 150° of Fahrenheit, either in a gloom stove, or by a temperature raised by means of steam, so as effectually to drive off all remaining humidity, which the charcoal or any deliquescent impurity that might accidentally be still in combination with the saltpetre may have induced.

Note.—The theory of gunpowder is this. The sulphur accelerates deflagration and supplies heat; the nitre supplies oxygen and nitrogen gases; and the carbon, by its strong affinity for oxygen, promotes the decomposition of the nitre, combining with its oxygen so as to produce carbonic acid gas. The sulphur melts at 226°, and under 280° forms a clear liquid of an amber colour, and below 600° it inflames. In the decomposition of gunpowder by explosion, the sulphur combines with the base of the potash to form a solid residuum as sulphuret of potassium, whilst 3 equivalents of carbonic acid and 1 of nitrogen are the gaseous products. The actual volume of gas is, when cold, 300 times the bulk of the gunpowder; but the explosive force is so augmented by the elevated temperature that it has been assumed as not less than 1000 atmospheres. The above noted qualities of sulphur point to some precautions in the arrangement and use of gunpowder, as the sulphur may by a very moderate temperature be made to run, and thus cake the gunpowder, independently of moisture.

Above 320° the liquid sulphur again thickens, so that the evil would be increased. In use, the low temperature at which sulphur will inflame indicates the necessity of great precaution in preventing the substances or machines with which it is brought in contact from being over-heated.—*Editors.*

The subsequent Proof and Practice of Gunpowder appertains especially to the Artillery Service. In the ordinary process of manufacturing gunpowder above described, the practical results are $\frac{8}{9}$ L.G. (large-grained) and $\frac{1}{9}$ F.G. (fine-grained); and this proportion fortuitously proved to be that of the average consumption in the late wars England has been engaged in.*

The Construction of the Buildings of a Gunpowder Manufactory has hitherto been principally of wood; but, besides that this material, when dry and seasoned, is of itself combustible, experience has shewn that its pores, as well as the connection of the framing of the building, become so impregnated with the dust, and liable to the lodgement of particles of powder, as to be highly inflammable and explosive: and therefore each building of wood is not only extremely liable to accident of that nature, but the ignited materials of an exploded building extend the danger to all parts of the establishment.

To remedy such a dangerous mode of construction is a subject of much interest to the Engineer Department; and it is suggested that the buildings be slight sheds of the best bricks, built with cement, having brick piers at the angles or jambs and to support the roof, which should be flat, with sides forming a shallow cistern, so that any ignited matter falling on it would be extinguished. Some establishments have also small cisterns immediately over the powder undergoing the different processes of manipulation, so that on any alarm the quantity in operation may be immediately immersed by the person attending it. The building should be lined with painted floor-cloth, a surface easily kept clean, and strong enough to prevent accidental damage from a blow, and less liable to degradation than plastering.

The buildings should be amply furnished with lightning conductors, and should be separated as much as possible by earthen and chalk traverses, formed at an easy slope, and planted; and the manufactory grounds should be intersected by rows of poplars, or other trees, so as to afford natural impediments to the extension of mischief from any partial explosion.—E. F.

H.

HEAT.†—Heat, in the ordinary application of the word, signifies, or rather implies the sensation experienced upon touching a body hotter, or of a higher temperature, than the part or parts which we bring into contact with it: in another sense, it is used to express the cause of that sensation. To avoid any ambiguity that may arise from this double use of the same expression, it is usual and proper to employ the word

* See note by Editors.

† Compiled by Lieut.-Colonel Portlock.

caloric to signify the principle or cause of the sensation of heat. On touching a hot body, caloric passes from it, and excites the feeling of warmth: when we touch a body having a lower temperature than our hand, caloric passes from the hand to it, and thus arises the sensation of cold.

Caloric is usually treated of as if it were a material substance; but, like light and electricity, its true nature has yet to be determined.

COMMUNICATION OF CALORIC.

Caloric passes through different bodies with different degrees of velocity. This has led to the division of bodies into *conductors* and *non-conductors* of caloric: the former includes such bodies as metals which allow caloric to pass freely through their substance, and the latter comprises those that do not give an easy passage to it, such as stones, glass, wood, charcoal, &c.

Table of the relative Conducting Power of different Bodies.

Gold	1000	Platinum	981
Silver	973	Copper	898
Iron	374	Zinc	363
Tin	304	Lead	180
Marble	24	Porcelain	12·2
Fire-brick	11	Fire-clay	11·4

With Water as the Standard.

Water	10	Elm	32
Pine	39	Ash	31
Lime	39	Apple	28
Oak	33	Ebony	22

Relative Conducting Power of different Substances compared with each other.

Hares' fur	1·315	Cotton	1·046
Eider-down	1·305	Lint	1·032
Beavers' fur	1·296	Charcoal	·937
Raw silk	1·284	Ashes (wood)	·927
Wool	1·118	Sewing silk	·917
Lamp-black	1·117	Air	·576

Relative Conducting Power of Fluids.

Mercury	1·000	Proof Spirit	·312
Water	·357	Alcohol (pure)	·232

RADIATION OF CALORIC.

When heated bodies are exposed to the air, they lose portions of their heat, by projection in right lines into space, from all parts of their surface.

Bodies which radiate heat best, absorb it best.

Radiation is affected by the nature of the surface of the body; thus, black and rough surfaces radiate and absorb more heat than light and polished surfaces.

Table of the Radiating Power of different Bodies.

Water	100	Blackened tin	100
Lamp-black	100	Clean "	12
Writing paper	100	Scraped "	16
Glass	90	Ice	85
India ink	88	Mercury	20
Bright lead	19	Polished iron	15
Silver	12	Copper	12

Reflection of Caloric differs from Radiation, as the caloric is in this case reflected from the surface without entering the substance of the body: hence the body which radiates, and consequently absorbs most caloric, reflects the least, and *vice versâ.*

SPECIFIC CALORIC.

Specific Caloric is that which is absorbed by different bodies of equal weights or volumes in attaining an equal temperature, based upon the law, acknowledged as universal, *that similar quantities of different bodies require unequal quantities of caloric to maintain any given temperature.* Dr. Black termed this, *capacity* for caloric; but as this term was supposed to be suggested by the idea that the caloric present in any substance is contained in its pores, and, consequently, the capacities of bodies for caloric would be inversely as their densities; and such not being the case, this word is apt to give an incorrect notion, unless it is remembered that it is but an expression of fact, and not of cause; and to avoid error, the word specific was proposed, and is now very generally adopted.

It is important to know the relative specific caloric of bodies. The most convenient method of discovering it is by mixing different substances together at different temperatures, and noting the temperature of the mixture; and by experiments it appears that the same quantity of caloric imparts twice as high a temperature to mercury as to an equal quantity of water: thus, when water at 100° and mercury at 40° are mixed together, the mixture will be at 80°, the 20° lost by the water causing a rise of 40° in the mercury; and when weights are substituted for measures, the fact is strikingly illustrated; for instance, on mixing a pound of mercury at 40° with a pound of water at 160°, a thermometer placed in it will stand at 155°. Thus it appears that the same quantity of caloric imparts twice as high a temperature to mercury as to an equal volume of water, and that the heat which gives 5° to water will raise an equal weight of mercury 115°, being the ratio of 1 to 23. Hence, if equal quantities of caloric be added to equal weights of water and mercury, their temperatures will be expressed in relation to each other by the numbers 1 and 23; or, in order to increase the temperature of equal weights of those substances to the same extent, the water will require 23 times as much caloric as the mercury.

The rule for finding by calculation, combined with experiment, the relative capacities of different bodies, is this:

Multiply the weight of each body by the number of degrees lost or gained by the mixture, and the capacities of the bodies will be inversely as the products.

Or, if the bodies be mingled in unequal quantities, the capacities of the bodies will be reciprocally as the quantities of matter, multiplied into their respective changes of temperature.

The general facts respecting specific caloric are as follows:

1. Every substance has a specific heat peculiar to itself, whence a change of composition will be attended by a change of capacity for caloric.

2. The specific heat of a body varies with its form. A solid has a less capacity for caloric than the same substance when in the state of a liquid; the specific heat of water, for instance, being 9 in the solid state, and 10 in the liquid.

3. The specific heat of equal weights of the same gas increases as the density decreases; the exact rate of increase is not known, but the ratio is less rapid than the diminution in density.

4. Change of capacity for caloric always occasions a change of temperature. Increase in the former is attended by diminution of the latter; a portion of the sensible heat becoming absorbed and latent, and *vice versâ.*

Tables of the Specific Heat of various Substances.

1. Air taken as unity.

	Equal Volumes.	Equal Weights.
Air	1·000	1·000
Hydrogen	·903	12·340
Carbonic acid	1·258	·828
Oxygen	·976	·884
Olefiant gas	1·553	1·576

The specific heat of the foregoing compared with that of an equal quantity of water:

Water	1·000	Hydrogen	3·293
Air	·2669	Carbonic acid	·221
Oxygen	·2361	Olefiant gas	·420

2. Water taken as unity, the weights equal.

Bismuth	·0288	Tellurium	·0912
Lead	·0293	Copper	·0949
Gold	·0298	Nickel	·1035
Platinum	·0314	Iron	·1100
Tin	·0514	Cobalt	·1498
Silver	·0557	Sulphur	·1880
Zinc	·0927	Mercury	·0330

ILLUSTRATION.—If 1 lb. of coal will heat 1 lb. of water to 100°, ·033 = $\frac{1}{30}$ of a lb. will heat 1 lb. of mercury to 100°.

The term *Capacity* for heat means the relative powers of bodies in receiving and retaining heat, in being raised to any given temperature; while *Specific* applies to the actual quantity of heat so received and retained.

When a body has its density increased, its capacity for heat is diminished. The rapid reduction of air to $\frac{1}{5}$ of its volume evolves heat sufficient to inflame tinder.

Table showing the relative Capacity for Heat of various Bodies.

	Equal Weights.	Equal Vol.		Equal Weights.	Equal Vol.
Glass	·187	·448	Silver	·082	·833
Iron	·126	·993	Tin	·060	—
Brass	·116	·971	Gold	·050	·966
Copper	·114	1·027	Lead	·043	·487
Zinc	·102	—	Water	·1	·1

Latent Caloric is that which is insensible to the touch, or incapable of being detected by the thermometer. The quantity of heat necessary to enable ice to assume the fluid state is equal to that which would raise the temperature of the same weight of water 140°; and an equal quantity of heat is set free from water when it assumes the solid form.

If 5½ lbs. of water, at the temperature of 32°, be placed in a vessel communicating with another one (in which water is kept constantly boiling at the temperature of 212°), until the former reaches this temperature of the latter quantity, then let it be weighed, and it will be found to weigh 6½ lbs., shewing that 1 lb. of water has been received in the form of steam through the communication, and re-converted into water by the lower temperature in the vessel.

Now this pound of water, received in the form of steam, had, when in that form, a temperature of 212°. It is now converted into the liquid form, and still retains

the same temperature of 212°; but it has caused 5½lbs. of water to rise from the temperature of 32° to 212°, and this without losing any temperature of itself. It follows, then, that in returning to the liquid state, it has parted with 5½ times the number of degrees of temperature between 32° and 212°, which are equal 180°, and $180° \times 5\frac{1}{2} = 990°$. Now this heat was combined with the steam; but as it was then not sensible to a thermometer, it was called *Latent.*

It is manifest, then, that a pound of water, in passing from a liquid at 212° to steam at 212°, receives as much heat as would be sufficient to raise it through 990 thermometric degrees, if that heat, instead of becoming latent, had been *Sensible.*

The sum of the sensible and latent heat of steam is always the same at any one temperature; thus, $990° + 212° = 1202°$.

If to a pound of newly-fallen snow were added a pound of water at 172°, the snow would be melted, and 32° will be the resulting temperature, 138° of heat becoming latent in the melted snow.

Latent Heat of various Substances.

Fluids.		Vapours.	
Ice	140°	Steam	990°
Sulphur	144	Vinegar	875
Lead	162	Ammonia	860
Bees'-wax	175	Alcohol	442
Zinc	493	Ether	302

Sensible Caloric is free and uncombined, passing from one substance to another, affecting the senses in its passage, determining the height of the thermometer, and giving rise to all the results which are attributed to this active principle.

To reduce the degrees of a Fahrenheit thermometer to those of Reaumur and of the centigrade; the zero of the Reaumur scale being at the freezing point, and 80° *at the boiling point, whilst the zero of the centigrade is at the freezing point, and* 100° *at the boiling.*

FAHRENHEIT TO REAUMUR.

RULE.—Multiply the number of degrees above or below the freezing point by 4, and divide by 9.

$$\text{Thus, } 212° - 32 = 180 \times 4 = 720 \div 9 = 80, \textit{ Ans.}$$
$$+24° - 32 = \quad 8 \times 4 = \quad 32 \div 9 = 3{\cdot}5, \textit{ Ans.}$$

or 3·5 below zero.

FAHRENHEIT TO CENTIGRADE.

RULE.—Multiply the number of degrees above or below the freezing point by 5, and divide by 9.

$$\text{Thus, } 212° - 32 = 180 \times 5 = 900 \div 9 = 100, \textit{ Ans.}$$

Or multiply the degrees of Fahrenheit by ·444 for reducing them to Reaumur, and by ·555 for reducing them to centigrade.

Medium Heat of the globe is placed at 50°; at the torrid zone, 75°; at moderate climates, 50°; near the polar regions, 36°.

The extremes of *natural heat* are from—70° to 120°; of *artificial heat*, from—91° to 36,000°.

EVAPORATION.

Evaporation produces cold, because caloric must be absorbed in the formation of vapour, a large quantity of it passing from a sensible to a latent state, the capacity

for heat of the vapour formed being greater than that of the fluid from which it proceeds.

Evaporation proceeds only from the surface of the fluids, and therefore *other things equal* must depend upon the extent of surface exposed.

When a liquid is covered by a stratum of dry air, evaporation is rapid, even when the temperature is low.

CONGELATION AND LIQUEFACTION.

Water on freezing gives out 140° of heat. Water may be cooled to 20°. All solids absorb caloric when becoming fluid.

The particular quantity of caloric which is required to maintain a substance fluid is called its caloric of fluidity, or latent heat.

The caloric absorbed in liquefaction is given out again in freezing.

Fluids boil in vacuo with 124° *less of heat than when under the pressure of the atmosphere. On Mont Blanc water boils at* 187°. This fact was ingeniously applied by Wollaston to the determination of altitudes by the temperature of the boiling point.

DISTILLATION.

Distillation is a double process, combining evaporation, or the formation of vapour, in the first instance; and in the second, condensation, or the reduction of that vapour to a liquid form. By this process the more readily vaporisable portions of bodies are separated from the more fixed, as alcohol from fermented liquors, water from saline solutions, mercury from amalgams. When the vapour is reduced to a solid form, as in the distillation of zinc, sulphur, &c., it is called sublimation. As the pressure of the atmosphere co-operates as a direct force in retaining bodies in their ordinary condition of solids or liquids, any diminution of that pressure must facilitate their assumption either of a liquid or gaseous form, and hence distillation in vacuo is much more rapid than it would be under ordinary circumstances; but as the vapour under diminished pressure has a greater capacity for caloric, there would be no ultimate saving of fuel by such an arrangement.

Table of Effects upon Bodies by Heat.

	Fahrenheit.
Cast iron, thoroughly smelted	2754°
Fine gold, melts	1983
Fine silver, melts	1850
Copper, melts	2160
Brass, melts	1900
Red heat, visible by day	1077
Iron, red-hot in twilight	884
Common fire	790
Iron, bright red in the dark	752
Zinc, melts	740
Quicksilver, boils	630
Linseed oil, boils	600
Lead, melts	594
Bismuth, melts	476
Tin, melts	421
Tin and bismuth, equal parts, melt	283
Tin 3 parts, bismuth 5, and lead 2, melt	212
Alcohol, boils	174
Ether, boils	98

	Fahrenheit.
Human blood (heat of)	98°
Strong wines, freeze	20
Brandy, freezes	7
Mercury, melts	−39

Wedgewood's zero is 1077° of Fahrenheit, and each of his degrees is equal to 130° of Fahrenheit.

Note.—Late experiments have shewn the previous computations for extreme heats to be erroneous.

MISCELLANEOUS.

FRIGORIFIC MIXTURES.

Mixtures.		Thermometer falls, or degrees of cold produced.	Degrees of Fahrenheit.
Nitrate of ammonia Water	1 part 1 „	46°	From + 50° to + 4°
Phosphate of soda Nitrate of ammonia Dilute nitric acid	9 parts 6 „ 4 „	71°	From + 50° to − 21°
Sulphate of soda Muriatic acid	8 „ 5 „	50°	From + 50° to 0°
Snow Muriate of lime	2 „ 3 „	53°	From − 15° to − 68°
Snow Dilute sulphuric acid	8 „ 10 „	22°	From − 68° to − 90°
Snow Potash	3 „ 4 „	83°	From + 32° to − 51°

EFFECTS OF HEAT.

Fahrenheit.	Wedgewood.	
− 90°	—	Greatest cold ever produced.
− 50	—	Natural cold at Hudson's Bay.
0	—	Snow and salt, equal parts.
+ 43	—	Phosphorus burns.
60° to 77	—	Vinous fermentation.
78	—	Acetous fermentation begins.
88	—	Acetification ends.
638	—	Lowest heat of ignition of iron in the dark.
800	—	Charcoal burns.
8490	57	Working heat of plate glass.
14337	102	Stone ware, fired.
16807	124	Greatest heat of plate glass.
25127	185	Greatest heat observed.

EXPANSION OF SOLIDS.

At 212°, the length of the bar at 32° considered as 1·0000000.

Glass	·0008545	Gold	·0014950
Platina	·0009542	Copper	·0017450
Cast iron	·0011112	Brass	·0019062
Steel	·0011899	Silver	·0020100
Marble	·0011041	Fire-brick	·0004928
Forged iron	·0012575	Lead	·0028436
Granite	·0007894	Zinc	·0029420

To find the expansion in surface or in volume, it must be remembered that each dimension of a solid experiences a similar proportional expansion.

Table of the Expansion of Air by Heat.—By Mr. Dalton.

Fahrenheit.		Fahrenheit.		Fahrenheit.	
32°	1000	50°	1043	80°	1110
33	1002	55	1055	85	1121
34	1004	60	1066	90	1132
35	1107	65	1077	100	1152
40	1021	70	1089	200	1354
45	1032	75	1099	212	1376

MELTING POINT OF ALLOYS.

Lead 2 parts,	tin 3 parts,	bismuth 5 parts,		melts at	212°
„ 1 „	„ 4 „	„ 5 „		melts at	246
	„ 1 „	„ 1 „		melts at	286
	„ 2 „	„ 1 „		melts at	336
Lead 2 parts,	tin 3 parts,			melts at	334
	„ 8 „	„ 1 „		melts at	392
„ 2 „	„ 1 „		common solder,	melts at	475
„ 1 „	„ 2 „		soft solder,	melts at	360

Boiling Points.—The boiling point of water, from 27 to 31 inches of the mercurial column, varies 1·65° for every inch, being at 30 inches 212°; and on this variation, as before stated, is founded the apparatus of Dr. Wollaston, since modified with some improvements by the French, for determining altitudes.

COMPARATIVE HEAT FROM VARIOUS FUELS.

1 lb. of tolerably good coal will raise the temperature of 60lbs. of water from 32° to 212°.

1 lb. of kiln or perfectly dried wood will effect the same on 35 lbs.

1 lb. of wood simply dried in the air „ „ 26 lbs.

1 lb. of charcoal „ „ 79 lbs.

Turf of good quality yields as much heat for equal weights as wood, and the heat it gives out by radiation whilst burning has been considered even greater than that of wood.

PRACTICAL DISTRIBUTION OF HEAT.

The distribution of heat in warming buildings may be regulated on either of the following systems or principles:

1. *By open Fire-places*, in which the air of the room is heated by radiation from the burning fuel. In this system, heating and ventilation are combined, as the smoke-flue continually draws away a large quantity of air which must be replaced by the external air entering either by doors, windows, or apertures specially contrived for the purpose. As much of the air drawn off has been heated, but not dispersed through the rooms or buildings, there is a great loss of heat in every apparatus of this kind, which increases in proportion to the force of draught and size of the throat of the flue. To obtain the greatest effect from an open fire-place, the throat of the flue should be no larger than is absolutely necessary to maintain an efficient draught, and should be so placed as to keep the radiating flame as long as possible in view; or if it be made on the Sandham principle, immediately above and at the back of the

fuel, the flame should pass behind a curved or inwardly-inclined metallic back, which would then become the radiating surface, as otherwise the loss of heat must be very great.

2. *By Stoves*, containing the fuel within them. The heat from iron stoves may be made very great, and they are therefore, when on good constructions, very efficient means of heating, were amount of heat alone to be considered; but as the quantity of air drawn off for the consumption of the fuel is comparatively small, and the air in contact with highly heated metal is much vitiated, they are inadequate as ventilators, and become injurious to respiration. Basins of water, placed on such stoves, remove the sense of dryness, but do not restore its purity to the vitiated air. By substituting for metal, less conductible materials, and increasing the quantity of matter to be heated, other forms of stoves are produced, which, by not heating the air in contact with them to so great a degree, are less objectionable, though as ventilators they are equally imperfect: the large German stoves are of this description.

3. *By Steam*.—The steam is on this principle carried by pipes through the buildings. If the temperature of the pipes falls below 212°, the steam is condensed, and, occupying as water only a very small portion of the pipes, their temperature rapidly decreases, and the change of temperature in the room is immediate. In keeping the temperature up to 212°, it is very difficult, the pipes being small, to avoid a dangerous augmentation of temperature, which may either lead to cracks of the pipes, or to accidents by inflaming substances in contact with them, and these are strong objections to this system. On this, and on the following systems, ventilation must be considered apart from heating, though the combustion of the fuel may here, as in fire-places, or in stoves, be made the prime mover of that operation.

4. *By Hot Water*, direct.—In this system, pipes are carried from a boiler, first directly to the rooms to be heated, and then return to the boiler. The circulation of the hot water through these pipes produces the heat, and as a very moderate elevation of temperature is sufficient to produce an efficient circulation of the fluid, there is no necessity of raising the heat in the pipes beyond 200°, the required temperature in the rooms being secured by the length and size of the pipes. This is a very great advantage, as it removes all chance of danger from accidental combustion, and of vitiation of the air by over-heating. The precaution to be taken is, so to regulate the expansion pipe and air-valve as to prevent any accumulation of air in elevated parts of the pipes, as the current would be stopped by its expansion and resistance.

5. *By Hot Water*, indirect.—Here the hot-water pipes pass through an air chamber, and the air thus heated is conducted by tubes or flues into the several chambers or rooms to be heated. This has an advantage in large military buildings, as the apparatus may be placed in a basement, and therefore, with the pipes, removed from the chance of injury.

6. *By Hot Water* (high-pressure).—Here the expansion of the water by the expansion tube is stopped, and the water is thereby allowed to attain a higher temperature than that of boiling water. Stronger, but smaller, pipes are here required, but as they are subject to accident from careless management, and become dangerous, like steam pipes, from accumulation of heat, the system is not to be recommended.

7. *By Hot Air*.—Here the air circulates round a stove or heater, and is then conducted by flues to the rooms; but as the air is vitiated in the same manner as by contact with common stoves, and may attain a dangerous elevation of temperature, the system is not equal to either 4 or 5.

The details of these methods will be given under 'Warming and Ventilation of Buildings.'—J. E. P.

HORSE—POWERS OF THE.*—The subject of horse power is one which we are rather diffident in entering upon, because nearly all that has been heretofore written upon it is unquestionably very deficient. In every one of the investigations on this subject that have fallen under our observation, the power which the muscles of the horse have to exert for the purpose of overcoming the resistance of his own body is a consideration wholly left out of view; and it is in vain that we look to such investigations for any one general expression of his *total power*, embracing his velocity, his stress available for draught, and the duration of his day's work.

It is not pretended that this very interesting subject is discussed in its fullest extent, yet it will be found that the general principles here developed are more accurate than any hitherto advanced, and that the conclusions deducible therefrom cannot fairly be questioned.

If a horse is not overworked, his muscles should not be fatigued more at the end of one day than another. The day's fatigue then of any given horse, when fairly worked, should be alike or constant. Let us denote this constant day's fatigue by M.

Again, the fatigue which horses suffer for any limit of time, say one hour, is different under different circumstances of speed and stress; and the length of time (T hours) which he can endure this fatigue each day will evidently be less according as that fatigue is greater, provided M at the end of the day's work remains constant. Representing therefore the fatigue for the limit of time generally by f, we have in all cases

$$M = f\,T.$$

Now f, or the muscular exertion expressed in the unit of time, depends on two principal elements, as we before said, namely, the stress and the velocity or space through which that stress is exerted during the unit of time. The stress is occasioned by the friction of the animal machine and the draught of the vehicle which he draws; and the space passed through in the unit of time is the velocity of motion (V). Consequently, if we denote the friction of the animal machine by p, and the available draught by P, we have

$$f = V \times (P + p).$$

Substituting this value of f corresponding to a unit of time in the preceding equation,

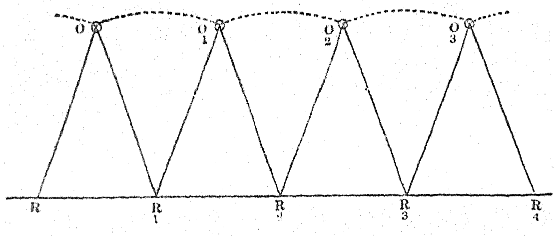
$$M = TV \times (P + p).$$

This expression involves all the objects of our inquiry; and from it we can obtain the available draught of the horse under all the circumstances of variable velocities and duration of days' work, or *vice versâ*, if we know the values of M and p.

Respecting the value of p, it will be evident from a little consideration, that it consists, like the friction of the mechanical machine, of three species of resistances, viz. the friction of the *joints* of the animal, that occasioned by the yielding of the ground beneath his feet, and the loss of momentum incurred at each step, similar to what takes place with the vehicle when it meets a projecting obstacle upon a road. To explain the general movement of the horse we must refer to fig. 1. It appears that when he is about to move, several parts of his body have a tendency to describe the arcs of circles whose centres are his feet and radii the length of his legs, and as he continues to move, those different parts are inclined to describe a succession of such arcs. Thus confining ourselves in the first place to moderate velocities, the path which those parts of the body are inclined to describe is represented by the lines

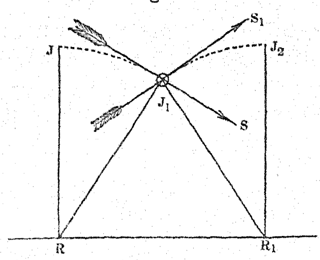
* By Edmund Leahy, C. E.

Fig. 1.



O O_1, O_1 O_2, O_2 O_3, &c., where O, O_1, O_2, &c., is the lower joint of the *humerus* or the *stifle joint* of the *femur* or thigh, and R, R_1, R_1, &c., the feet of the animal. At a quick pace, when the horse trots or gallops, the path described will be so many curves of a parabola. Thus we see that a portion of the momentum must be lost at each step on account of the mechanism of the horse, as his motion will be analogous to that of a wheel going over a number of obstacles; for the momentum in the direction J_1 S_1 (fig. 2), will be less than that acquired in the direction J_1 S, and one set of muscles in the descending portion J J_1 of each step must generate an additional velocity that will compensate in part for this consequent loss, while another set compensates for the remaining part by yielding to the weight of the body in the ascending portion J_1 J_2.

Fig. 2.



It would appear, therefore, that the resistance from the change of direction of motion which thus takes place at each step must be very considerable, and that it is of such a nature as varies directly as the square of the velocity, if we confine ourselves to the consideration of an external agent of locomotion, as that of an external pressure or draught which may be supposed to be self-acting, and thereby maintained in an uniform speed. But in the case of the animal machine, the muscles of the bony (principally those adjacent to the *humerus* and *tibea*), which are the source of power, are themselves moved forward at the velocity of the horse, and consequently the stress upon them for overcoming this species of resistance will vary but as the velocity.

To give a further proof of our views respecting the muscular power which must be expended in maintaining the momentum, we have to state that the resistance (in the simple acceptation of the term) to uniform notion (no matter by what agency that resistance is overcome) is affected by the same laws in the case of the animal as the mechanical machine, and consequently must vary as the square of the uniform velocity maintained. The *constant pressure* which must be applied to the machine varies as the square of the velocity or V^2, and may be expressed generally by gV^2, in which g represents the constant suited to a particular case which defines the general variation. Now if the agent were an external force, such as a weight passing over a pulley or a steam engine, the work expended in moving the machine a unit of space (S) is evidently represented by the pressure × the space passed through or, $S \times gV^2$. It will also be evident that the *muscular* work of the horse expended in maintaining the like pressure gV^2 on his body will be represented by gV^2 × the space through which the muscles acted or rather were expanded. Again, *cæteris paribus*, we

know the space through which the principal muscles will have expanded themselves in the passage of the horse over a unit of space, say one mile, varies as the time. But the time $\propto \frac{1}{V}$; therefore the muscular work expended in maintaining a uniform momentum is expressed by $gV^2 \times \frac{1}{V} = gV$. Consequently the stress or muscular work corresponding to a unit of space generally varies as V, or the velocity.

Hence, if this stress is represented by c, in the cases of horses of ordinary size, moving at the rate of $2\frac{1}{2}$ miles per hour, it must be represented at any other velocity (V) by

$$c \times \frac{V}{2\frac{1}{2}}.$$

The amount of friction of the joints of the horse we have no correct means of ascertaining; but the resistance to motion from such a cause can be but very little. Reasoning upon the determination of the resistance due to the friction of the axles of machines in general, and supposing the friction of the rubbing surfaces of these joints not to be more than that of like surfaces of best mechanical workmanship, this resistance may be expressed by

$$\frac{w}{20} \times \frac{1}{40} = \frac{1000}{800} = 1\tfrac{1}{4} \text{ lbs.},$$

in which expression the length of the horse's leg is supposed to be 40 inches and the diameter of the joints 2 inches, and w, or the weight of the horse, 1000lbs.

The resistance to motion occasioned by the sinkage of the feet in the ground, although of importance when the surface is penetrable to a considerable degree, yet will be found of little moment upon a road in an ordinary travellable state of repair. It is evident the extra muscular exertion which must be spent in all such cases above that necessary upon a hard surface is equal to the amount of *work expended* in pressing the horse's feet through the surface upon which he walks.

Let us represent the greatest depth to which the foot sinks by D, any lesser depth by x, the weight of the horse by w, and suppose the resistance to vary as the n^{th} power of the depth penetrated. Then the *work expended* in compressing an element of depth is

$$d\,w = w \times \frac{x^n\,dx}{D^n} \therefore w = \frac{w}{D^n} \times \int_D^0 x^n\,dx = W\,\frac{D}{n+1}.$$

This expenditure of power occurs at each step or length (l) passed over, and is equivalent to the force of gravity upon a plane whose sine of angle of acclivity is $\frac{D}{l\,(n+1)}$. The resistance from the sinkage of the feet will therefore be the same as the constant stress:

$$w \times \frac{D}{l\,(n+1)}.$$

To exemplify this, suppose in ordinary cases $D = \frac{1}{4}$th of an inch, $l = 30$ inches, and $n = 2$. The expression will then be

$$1000 \times \frac{\frac{1}{4}}{30 \times (2+1)} = \frac{1000}{360} = 2\tfrac{3}{4} \text{ lbs.}$$

If we now substitute the value of p, we have

$$M = TV \times (P + c\,\frac{V}{2\frac{1}{2}} + 4).$$

Now let us suppose that an ordinary good horse is capable of drawing on a level

road, in his usual day's work, one ton weight besides the car, at a velocity of $2\frac{1}{2}$ miles per hour for 6 hours, and that four other such horses, under like circumstances draw a stage coach with passengers, &c., at a velocity of 10 miles per hour, a distance of 8 miles, or for $\frac{4}{5}$ths of an hour; the value of P will in the former case be 120lbs. and in the latter 40lbs. Inserting these respective values of T, V, and P, and observing that under all circumstances M is constant, we therefore have

$$15 \times (124 + c) = 8 \times (44 + 4\,c)\ 17\,c = 1508 \therefore c = 88{\cdot}8 \therefore 15 \times (124 + 88{\cdot}80) = M = 3192.$$

Substituting now the obtained values of c and M,

$$TV \times (P + 35\tfrac{1}{2}\,V + 4) = 3192.$$

In these calculations, let it be remembered that T represents the duration of the day's work in *hours*, V the velocity in *miles* per *hour*, and P the stress in *pounds avoirdupois*.

There results the following independent expressions for level roads:

$$P = \frac{3192}{TV} - \left\{35\tfrac{1}{2}\,V + 4\right\}.$$

$$T = \frac{3192}{V \times (P + 35\frac{1}{2}\,V + 4)}.$$

$$V = \sqrt{\frac{90}{T} + \frac{(P+4)^2}{5041}} - \frac{P+4}{71}.$$

To give an example: Let it be required to find the available draught of a horse upon a level road, if he draws at the rate of 5 miles per hour for 3 hours each day. Here $V = 5$, and $T = 3$. Substituting therefore in the equation

$$P = \frac{3192}{3 \times 5} - (35\tfrac{1}{2} \times 5 + 4) = 31\tfrac{1}{3}\text{ lbs.}$$

Again, let it be required to find the velocity with which a horse can accomplish his day's work when he draws for 2 hours with an available force of 40lbs. In this case $P = 40$, and $T = 2$; then

$$V = \sqrt{\frac{90}{2} + \frac{44^2}{5041}} - \frac{44}{71} = 6{\cdot}08 \text{ miles per hour.}$$

It is evident all such deductions as those we have now obtained must be confined within certain limits. For instance, the constitution of ordinary horses renders them unable to exert a greater available power of draught than about 300lbs. to endure a longer day's work than about 8 hours, exclusive of the time occupied in feeding and resting, or to attain a higher velocity than about 15 miles per hour.

From the stress on a horse attributable to the motion of his load W, up or down a hill which is inclined at an angle S to the level, is

$$W \times \left\{\cos. S \times \text{tang.}\,(R + a) + \sin. S\right\}.$$

Assuming $\text{tang.}\,(R + a) = \frac{1}{25}$ in ordinary cases, and $\cos. S = 1$, this expression will become

$$W + \left(\frac{1}{25} + \sin. S\right).$$

Going down a hill, when sin. S is greater than $\frac{1}{25}$, the expression becomes negative, which shews that the stress is in an opposite direction to motion, for the purpose of

keeping the load within an uniform velocity. Under any circumstances therefore the resistance of the load will be

$$\textit{On a level, } P = \frac{W}{25};$$

$$\textit{Ascending, } P = W \times \left(\frac{1}{25} + \sin. S\right);$$

$$\textit{Descending, } P = W \times \left(\frac{1}{25} \backsim \sin. S.\right.$$

In like manner, and for the same reasons, the value of p, or the stress which a horse suffers in moving *himself*, will be

$$\textit{On a level, } p = 35\tfrac{1}{2}\,V + 4;$$

$$\textit{Ascending, } p = 35\tfrac{1}{2}\,V + 4 + w \sin. S;$$

$$\textit{Descending, } p = 35\tfrac{1}{2}\,V + (4 \backsim w \sin. S).$$

If we substitute the particular values of P and p, we have the following three general expressions from which V, W, or T may be determined in the case of ascending and descending, as well as level roads.

$$\textit{On a level, } T\,V \times \left\{\frac{W}{25} + 35\tfrac{1}{2}\,V + 4\right\} = 3192.$$

$$\textit{Ascending, } T\,V \times \left\{W \times (\tfrac{1}{25} + \sin. S) + 1000 \sin. S + 4 + 35\tfrac{1}{2}\,V\right\} = 3192.$$

$$\textit{Descending, } T\,V \times \left\{W \times (\tfrac{1}{25} \backsim \sin. S) + (4 \backsim 1000 \sin. S) + 35\tfrac{1}{2}\,V\right\} = 3192.$$

That part which is contained between the braces (or $P + p$) is the intensity of the muscular action; and we should think its maximum value in general for a day's work cannot exceed that of a horse which draws a net load of 2 tons, or a gross load of 5500 ℔s., at $1\frac{1}{2}$ miles per hour on a level road. According to this supposition the maximum value of the intensity of action would be 277 ℔s. in an ordinary day's work.

The following Table shews the velocities with which an ordinary horse can draw different loads for 8 hours a day on a level road.

Duration of Day's work 8 hours. Friction 1-25th of gross load.			Duration of Day's work 8 hours. Friction 1-25th of gross load.		
Gross load in ℔s.	Draught of load in ℔s.	Velocity in miles per hour.	Gross load in ℔s.	Draught of load in ℔s.	Velocity in miles per hour.
No load.	0	3·29	3250	130	1·96
250	10	3·14	3500	140	1·89
500	20	3·04	3750	150	1·82
750	30	2·92	4000	160	1·76
1000	40	2·80	4250	170	1·70
1250	50	2·68	4500	180	1·65
1500	60	2·57	4750	190	1·60
1750	70	2·47	5000	200	1·55
2000	80	2·36	5250	210	1·50
2250	90	2·28	5500	220	1·45
2500	100	2·20	6000	240	1·36
2750	110	2·11	6500	260	1·29
3000	120	2·03	7000	280	1·22

A subject of great importance presents itself to our notice here; namely, the

determination of the effects of inclinations on roads where horse power is employed as the means of transport.

We all know, even without going into calculations, that an up and down road, when the inclinations are at all considerable, cannot be so favorable for the draught of heavy loads as the level road, because the advantages to be derived from the descent do not compensate in full for the disadvantages from the ascent. Our object now is to determine with accuracy the amount of this deficiency, with the view of enabling us to form a just comparison between different lines of road connecting the same termini, as well as to ascertain how much the Engineer would be warranted to increase the length of road for the purpose of lessening the inclinations or obtaining a level.

If one ton be assumed as the net load of a horse, his gross load will be 2240lbs. + 760lbs., the weight of the car, = 3000lbs.; and if 8 hours be taken as the duration of his day's work, then his velocity ascending a plane of 1 in 40 will be 1·45 miles per hour, and with the same load upon a level it would be 2·03 miles per hour. Thus while he advances a distance of 1·45 miles up the inclination, he would have been able to travel 2·03 miles on a level; consequently the carriage on 1·45 miles of the ascent is as expensive as on 2·03 miles of the level. And 1·45 : 2·03 : : 1 : 1·4 miles, the length of a horizontal plane, which is equivalent to 1 mile of the ascending plane of 1 in 40.

Again, descending the same plane with the same load, the velocity will be 2·55 miles per hour. Then 2·55 : 2·03 : : 1 : 0·79 miles, the length upon a level equivalent to 1 mile of the descending plane.

Therefore, ascending and descending

1·40
0·79
———
2·19
———
1·095 mean equivalent horizontal plane.

From this we see that 10 miles of a road having a plane or a continued succession of planes of 1 in 40 is equivalent to nearly 11 miles of a level road.

The following Table of equivalent horizontal planes has been computed for other inclinations in a similar manner. It is however necessary to state that all acclivities greater than 1 in 25 were reduced to that inclination by increasing the unity of length, because the muscular stress of the horse on that rise $\frac{3000}{25} + 120 + 4 + 42 = 286$ lbs., being about the utmost he could endure; and if the rise is steeper, he must go partly from one side of the road to the other, so as to bring the stress within that limit. For the same reason, all declinations steeper than 1 in 9·8 were reduced to that plane.

For instance, upon a rising plane of 1 in 10, the muscular stress upon a horse is equal very nearly to the draught on a level + the force of gravity from the incline, or $120 + 4 + 42 \frac{3000}{10} = 466$ lbs., which far exceeds the limit of his power. In such case, therefore, he must in advancing 1 mile directly up the inclination traverse from side to side an acclivity of 1 in 25, and actually travel a greater distance.

Table shewing the Lengths of Horizontal Lines equivalent to several Ascending and Descending Planes; the length of the Plane being unity.

An ordinary Horse supposed to work 8 hours a day, and to draw a gross load of 3000 lbs., or a net load of 1 ton.			
	Equivalent Horizontal Lines.		
Planes.	Ascending.	Descending.	Mean of the two.
1 in 5	8·32	3·27	5·79
10	4·16	1·65	2·90
15	2·90	1·06	1·98
20	2·08	0·83	1·45
25	1·66	0·70	1·18
30	1·55	0·74	1·14
35	1·45	0·77	1·11
40	1·40	0·79	1·09
45	1·35	0·81	1·08
50	1·31	0·83	1·07
55	1·285	0·84	1·062
60	1·261	0·853	1·057
65	1·238	0·860	1·049
70	1·215	0·871	1·043
80	1·194	0·879	1·036
90	1·173	0·890	1·031
100	1·154	0·898	1·026
150	1·103	0·919	1·011
200	1·074	0·931	1·0025
Level.	1·000	1·000	1·0000

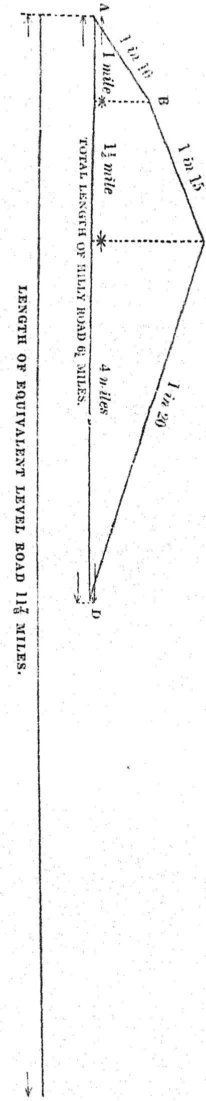


Fig. 3.

The length of a horizontal road which would be equivalent to a hilly one, such as the section A B C D (fig. 3), may at once be ascertained by multiplying the length of each plane respectively by its tabular numbers, as given in the fourth column, and adding the products together. The sum will be the required length of a level road which could be travelled over in the same time and with the same expenditure of power.

Thus, supposing the intercourse to be as much in one direction as in the other,

From A to B, 1 mile × 2·9, the tabular number for a plane of 1 in 10 is . .	2·90 miles.
From B to C, 1½ miles × 1·98, the tabular number for a plane of 1 in 15 is . .	2·97 miles.
From C to D, 4 miles × 1·45, the tabular number for a plane of 1 in 20 is . .	5·80 miles.
Equivalent horizontal road	11·67 miles.

QUALITIES OF THE HORSE.*

From time immemorial the powers of this noble and generous animal have been made subservient by man to the purposes of war. The predatory Arab, the chivalrous Cossac, the adventurous Roman, and the patriotic Greek, have each in successive

* By Opie Smith, V. S., 2nd Dragoon Guards.

ages, and in various manners, trained him for co-operation and assistance in their offensive and defensive movements in the battle-field.

In the present time, as in the past, his great powers are equally engaged and appreciated; and no army can possibly be effective, or complete, without his valuable and arduous services.

The horse, as employed in European armies, may be classed under the following heads, viz. 'The Artillery,' 'the Heavy Dragoon,' 'the Light Dragoon,' and the 'Pack-Horse.'

For 'Artillery Horse,' see p. 246.

The heavy dragoon horse is, or ought to be, a description of animal between the artillery and light dragoon horse: but recent regulations respecting recruiting are rapidly removing the distinction once so prominent between the heavy and light dragoon horses.

The average weight which a heavy dragoon horse has to carry is about 18 stone 11 lbs., and includes the dragoon and his appointments: to this are added on Service one day's ration for the horse, weighing 20 lbs., and one for the man, weighing 6 lbs.; making a total of 20 stone 9 lbs.; an immense weight for a horse to support, and necessarily requiring a powerful animal to move under in rapid evolutions.

Heavy dragoons are principally employed in the field, in charging cavalry and infantry, attacking guns, and covering retreats.

There is no description of horse used in the Service which requires a more cautious selection in purchasing than the heavy dragoon horse; for if coarse and under-bred, he is too slow for field movements; and if well-bred, but not possessing bone and substance, is too weak to carry the weight, and too light to withstand the shock of a cavalry charge. Perhaps a better description of what the war-horse should be, cannot be given, than that described by Virgil; which corresponds precisely with our idea of the heavy dragoon horse.

> "Illi ardua cervix,
> Argutumque caput, brevis alvus, obesaque terga;
> Luxuriatque toris animosum pectus: honesti
> Spadices, glaucique; color deterrimus albis,
> Et gilvo: . . . .
> At duplex agitur per lumbos spina; cavatque
> Tellurem, et solido graviter sonat ungula cornu."

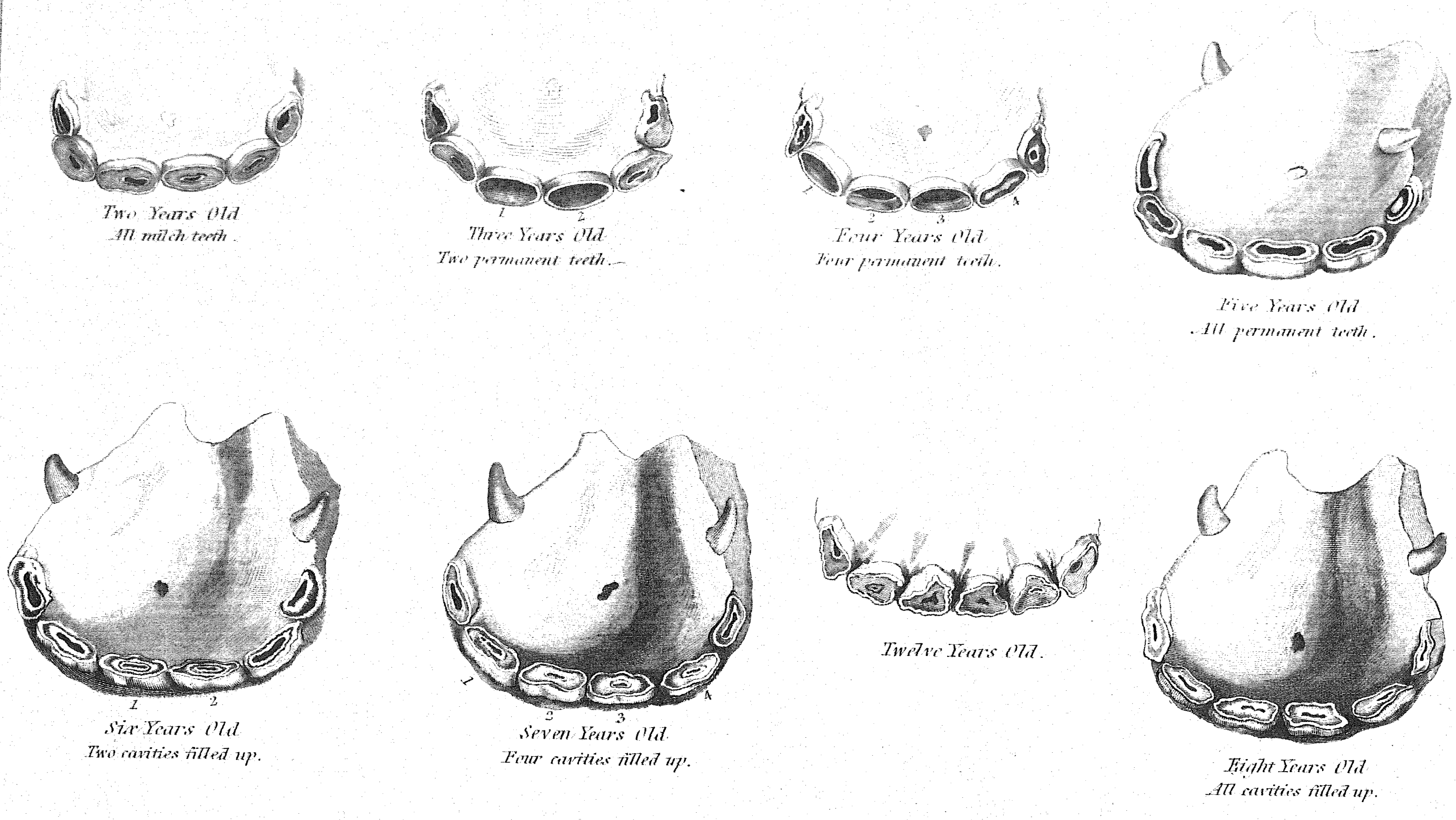
The light dragoon horse ought to be faster, more active, and higher bred, than the heavy; as his duties in the field are generally performed in quick movements, such as carrying dispatches, pursuing an enemy, &c.

Although light dragoon regiments are allowed to enlist smaller men than the heavy, still the average weight to be carried by their horses is nearly equal to that of heavy dragoons; which circumstance tends materially to militate against their speed, and consequently the utility of their operations.

The heavy and light dragoon horses are purchased between the ages of three and five years. The price granted by Government for each horse is £26. 5*s*., excepting the Life Guards and Scot Greys.

The pack-horse is employed on Service only for carrying regimental baggage, hospital and regimental stores, &c. He is generally a short-legged compact little horse, very strong, and sure-footed. Mules are sometimes used for the same purposes.

Age.—The age of the horse is determined by the appearance of the teeth, which vary according to the number of years the animal has attained, and may be easily



...s Smith del.

J.W. Lowry fc.

London. John Weale, High Holborn. 1848.

understood by a slight attention to the subject; the amount, quality, and size of the teeth, indicating the repective ages. (See Plate.)

All cavalry horses, or horses intended for the Service, date their age from the 1st of May: but it must be very evident that there might be a variation of several months between the different periods of their births: hence arise the terms 'an early or a late foal.' To this circumstance in particular, and the deception occasionally practised by breeders,—of knocking out the colt's teeth,—the Officer employed to purchase remount horses should direct his attention; or he will be liable to imposition, and subject himself to the annoyance of having his purchases rejected, on account of age, at the Head-Quarters of his regiment.

Cavalry remount horses are usually taken between the ages of three and five years; one year making a material difference in their market value: breeders and sellers, aware of this circumstance, occasionally endeavour to make the colt appear a year older than he actually is: to effect this, they force out the colt's teeth, which are naturally replaced by the permanent ones in succession; giving a false indication of the age of the animal. To an experienced person the deception is easily detected, and a very little attention to the subject will enable any one to do the same.

We will suppose a colt to be nearly three years old, the age most likely to be practised upon: he ought at this time to have two permanent and four milk teeth in his lower jaw: the seller wishes to pass him as rising four-year old; to do this, he knocks out the two teeth next to his permanent ones, leaving two permanent teeth in front and two colt's teeth at the corners; thereby shewing that the colt is putting up his four-year old teeth, although at the time he has not completed his third year.

It certainly requires some experience to detect, at once, this attempt at imposition; but the buyer should carefully examine the upper jaw, to ascertain if the teeth in it correspond with the lower ones; for the deception is frequently confined to the lower jaw, as being the most commonly examined. If the teeth do not correspond, depend upon it fraud has been attempted; for the upper teeth are usually shed before the lower ones. There will also be a wound-like aperture of the gums, not to be mistaken, or an attempt of nature to fill up the vacuum caused; which the succeeding permanent teeth are not sufficiently developed to do. These indications, added to the small and young appearance of the front pair of nippers, and colt-like formation of the animal, will in most instances be a sufficient guarantee against deception.

The lower front teeth or nippers are those by which the age of the colt is usually determined. At two years old, these teeth will be complete; that is to say, the colt will have a full set, six in number, of milch teeth, as shewn in the accompanying Plate.

Between two and three years old, the two centre teeth are displaced, and two permanent teeth succeed them, easily distinguished from the colt's teeth by being broader, larger, and having a dark cavity in the centre of the upper surface.

At three years old, the colt will have in the lower jaw, two permanent and four colt's teeth: between the third and fourth year, the next pair of incisor teeth will be shed, and permanent teeth succeed them.

At four years old, there will be four permanent teeth in the centre, and two colt's teeth at each corner, of the lower jaw. Between the fourth and fifth year, the last remaining colt's nipper or corner teeth will be cast; and if a horse or gelding, the tushes, four in number, will shew themselves; two in the upper, and two in the lower jaw.

At five years old, the horse will have a full or complete set of permanent teeth in

the upper and lower jaw; for the same change as stated to take place in the lower, is developed in the upper jaw also. The colt at this age takes the name of horse, and is supposed to be equal to all the laborious duties expected from him. Although we can no longer judge of his age by the shifting or shedding of his teeth, we can form a tolerably correct conclusion from other appearances of them.

At six years old, the dark oval-shaped mark in the centre of the two front nippers, usually called by horsemen 'the bean,' will be nearly or quite worn away; the tushes higher and stronger, and the cavities of the interior part of the tooth more filled; the two corner nippers level with the others, and equally developed.

At seven years old, the marks in the second pair of nippers are filled up, and the tushes become more round externally and internally.

At eight years old, the marks in the corner nippers are worn out, and the tushes more round and blunt. From this age, the animal is said to be, in horse phraseology, 'past knowledge;' and although a tolerably correct opinion may be formed for many years to come, by the appearance of the upper jaw, and other prognostics, still they cannot be implicitly relied upon. It often occurs at a much earlier period, that the best judges of age are deceived by the untimely structural alteration of the teeth produced by mechanical or pathological causes; such as cribbiting, biting the rack or manger, eating hard food, &c.; and the purchaser would do well, if he supposes that the marks are prematurely obliterated, to satisfy himself that the cause of erasure does not arise from the vicious habit of cribbiting.

The natural energies of the horse may be said to be at their zenith between the ages of six and nine years, and compared to the relative age of a man between twenty-five and thirty-five years,—provided that the functions of the animal have not been destroyed by early ill-usage, or over work. Many instances of longevity in the horse are credibly attested; thirty, forty, and even sixty years, have been attained. (See Plate 'Horse.')

As a particular instance, and one occurring of late date, we will mention, that at the review which took place on the 18th of June, 1846, in the Phœnix Park, Dublin, a horse, ranked, passed the General commanding, ridden by an old veteran, both horse and rider having been engaged in the ever-memorable battle of Waterloo: supposing the horse to have been five years old at the time of the engagement, he must be, at the present period, at least thirty-six years old; and the probability is that he is much older.

The Stable.—It is impossible to lay down any general rules to regulate the construction of private stables; existing circumstances, such as situation, elevation, size required, number of horses to be accommodated, means of the proprietor, &c., must be considered, and will govern the formation; but this is not the case with the building of Barrack Stables, there being generally plenty of ground, and a sufficient site to construct any description of stable building: the principal calculation to be made is the number of troop horses to be stabled; and as stations are usually intended to contain whole regiments, squadrons, troops, or detachments, very little difficulty arises on this head. The next considerations are, the shape of the building, the number of horses each stable should accommodate, and a prudent attention to ventilation. Experience proves that the most sheltered stables are the most healthy; that is, those most sheltered from high winds and excessive currents of air; but so constructed as to allow of a pure and free ventilation of that element, provided that the situation is not low or swampy.

When stables are built for the reception of single troops, or detached parties, the site, shape, and arrangement will necessarily be much governed by the situation, locality, and other circumstances; but where ground is to be laid out for the purpose

of stable building, for the accommodation of whole regiments, or even squadrons, then it becomes a matter of great consideration what is the best plan for convenience and utility, as well as to secure the health of the horses which are to occupy them. I have already stated that stables exposed to strong currents of wind are highly objectionable, and that those which are most sheltered are the most healthy. As it frequently happens that there is no natural or artificial shelter available for the purpose, I consider that the best shape for the construction of troop stables is that of a square, or squares; so that from whatever quarter the wind may blow, one side will always present a screen, or barrier, to the tempest, and protect in a great measure the three remaining sides from its violence, and afford shelter to the horses during exercise or parade within its area. The size of the stables is a subject requiring much consideration, and to which sufficient attention is not generally applied: small stables are like small rooms, which are always very hot or very cold; and, generally speaking, all attempts at ventilation produce in them direct draughts, or injurious currents of air. Troop stables ought to be large enough to hold at least twenty horses. To effect this, I would advise that the stables be sufficiently wide to admit of the racks and mangers being attached to the walls on either side of the building, and a sufficient space allowed for a passage in the centre, wide enough to prevent the horses from reining back upon each other. In a long range, the stables should have doorways between each; so that in warm weather, when thrown open, a free circulation of air would be kept up from one end to the other, at the same time affording an easy method of communication. Too many entrances to the stables should be avoided; one at each end are quite sufficient, and answer every purpose for ingress and egress; at the same time they operate as most efficient and useful ventilators. In the small troop stables, as now generally constructed, the horses occupying the stalls on the reverse side to which the door is attached, are exposed, when the doors are opened, to a direct current of air; while those in the other corners suffer from impure atmosphere and want of ventilation. It is a curious fact, that during the prevalence of Influenza, and other Epizootics, I have noticed that four cases out of five occur with the horses standing in corner stalls; while those occupying the stalls exposed to the current of air from the open doors have been afflicted with paralysis, and even locked-jaw.

I would recommend that the space of one stall, in every stable, properly partitioned off, be appropriated for the keeping of the daily rations of hay and corn, as great waste is often occasioned by its being placed in an empty stall, or exposed, outside the stable, to the inclemency of the weather; and that the space between the horses, in the centre of the stables, be sufficiently wide to allow the litter to be piled up on rainy or boisterous days.

The racks, mangers, and posts, to be made of iron; in fact, too little wood-work cannot be used in the construction.

Particular care should be paid to the drainage of the stalls, but no more inclination should be permitted than just sufficient to answer the purpose: too great a declivity throws an injurious stress upon the tendons of the hind extremities, causing sprains, spavins, wind-galls, &c.: an inclination of four inches from the top of the stall to the gutter or drain at the bottom is quite sufficient to answer the purpose of drainage.

To prevent the accumulation of urine, fæces, and other offensive matter, between the interstices of the paving of the stalls, the stones should be so laid as to form, as nearly as possible, a flat surface; cement, impervious to wet, should be used between each stone. The flooring formed by the small pebble-stones, now very generally used, is of the very worst description, as it admits the urine to soak between them,

completely saturating the sub-surface, causing the generation of the most deleterious gases, and moreover is constantly out of repair.

A great variety of opinions exist respecting the propriety of making ceilings to the roofs of troop stables; but provided the stables are sufficiently lofty, say eleven or twelve feet high, and the ventilators judiciously arranged, I think it is of very little consequence whether the stables have ceilings or not.

The doors and windows should be so arranged, that in the summer time they might be left open: half doors are preferable to whole ones; that is, the doors should open half from the top and half from the bottom; the lower half being kept shut prevents a horse escaping from the stable in the event of his getting loose. This arrangement for infirmary loose boxes is almost indispensable, as the sick horse can have the advantage of the pure air, without being exposed to rain or wind.

Stable, Management of.—Under this head are included, feeding, watering, grooming, exercise, ventilation, and all matters which appertain to the general management of the animal; so as to keep him in the best possible health, and in that condition which enables him to perform the duties required from him with the least expenditure of his natural functions.

Feeding.—The quantity of food considered sufficient to support the energies of the troop horse is twelve pounds of hay and ten pounds of oats; and, generally speaking, if the quality is good, it is found sufficient for the purpose. These rations are divided into three feeds, given, one in the morning, one at mid-day, and one in the evening. Bran is sometimes substituted for corn, mixed with water to form a mash; it acts as a mild laxative, and tends to prevent fever and costiveness. In winter, bran is usually given to troop horses once a week; but in hot weather it will be found advisable to give it oftener: from its laxative qualities, and easy digestion, it is one of the best, at the same time one of the safest, remedies as an alterative, that the veterinarian or owner can administer. For the infirmary stables, it is indispensable; and no horse can with safety be physicked, unless he has been fed, at least, twenty-four hours upon it: made into hot mashes, and given at night in a pail, so as to steam the head of the patient, it is an excellent remedy for catarrhs and coughs. The usual allowance given by contractors, in lieu of ten pounds of oats, is eleven pounds of bran; which, from its light weighing, forms a considerable bulk. Very few horses, although unfit to do much work when fed entirely upon it, lose their flesh or appearance. In all diseases of the digestive organs, hide-bound, fevers, &c., it is invaluable, and for which at present we have no substitute.

The properties of oats and hay are generally so well understood, that the subject requires little comment. All persons conversant with the management of horses know that musty, as well as mow-burnt hay, are highly injurious to their health, and should be carefully avoided: the same may be said of oats that are kiln-dried, or become sour, by being placed in bulk when damp, or not properly harvested. Oats that are kept in store, in large quantities, should be turned over at least twice a week, or they will ferment, and become unwholesome: the neglect of this precaution has caused many Officers to reject corn as unfit to issue, which was perfectly good when passed into store.

Good meadow hay, which contains a full share of herbage, and well saved, is preferable to clover or any artificial grasses.

I have found great benefit from giving green food in summer, for a short time, not exceeding eight or ten days. Tares or vetches are preferable to clover; but when neither of these can be obtained, meadow grass is a good substitute: it acts gently upon the bowels and kidneys, prevents the necessity of medicine without materially altering the condition, removes swollen legs, cracked heels, hide-bound, &c. Horses

should not work while eating green food; but as troops are at all times liable to be called upon to perform unforeseen duties, it is advisable that a certain portion only should be submitted at a time to this feeding, leaving the remainder fit for Service.

Remount Horses—Stabling of.—The management, or what is generally termed the stabling, of young or remount horses, claims particular attention. There is no animal which man has domesticated, experiences so great and so sudden a change in his habits, customs, feeding, and exercise, as does the young horse when first taken up from pasturage, and placed in the stable; which is in future to be his almost constant dwelling. From freedom he is doomed to constant restraint: accustomed to seek his own food, he now eats nothing but what is served to him; from exercise dictated at will, he now obeys the direction of his rider; from pursuing the impulse of his own motives, he must now implicitly obey that of man: in fact, it is a change from nature to art,—from freedom to slavery. This change is indicated by the diseases which generally follow it,—strangles and fever are the most prevalent; and although not usually attended with danger, if proper precautions are adopted, still they have a decided influence upon the constitution of the animal.

When young horses are first placed in a stable, great care should be taken that it is kept cool and clean, with a proper supply of fresh air; and, above all, not to allow too many horses to occupy one stable. Their provender, at first, should be green food, if procurable, with oats; but if that cannot be obtained, bran mashes, or bran and oats mixed: but when given mixed, the bran should not be wetted; for if so, it enables them to swallow it without mastication. Young horses should be allowed as much water as they will drink: for this purpose a pail should be fastened within their reach; or, if the stable has iron mangers, a spare stall between each horse will allow of one manger being used as a reservoir. An occasional mild dose of physic will be found beneficial; excessive purging is to be avoided. As the animals become more accustomed to the stable, the bran may be reduced, and more oats substituted; at the same time the exercise should be increased.

Watering of.—Soft water, such as pool or rain water, is the best for horses: spasmodic colic sometimes arises from giving horses water just taken from a well or pump. Non-commissioned officers should be instructed to pay particular attention to the watering of troop horses, as it frequently happens that an indolent or careless dragoon will not give his horse a sufficient quantity, if he has any distance to fetch it. I have known many horses fall off in condition by being kept short of water, and others to put up flesh, by having water so placed that they could help themselves at any time, or in any quantity.

Grooming of.—Many persons imagine that grooming is merely intended to clean the horse, and give him a fine coat; but besides these, its effects are much more beneficial, by producing circulation of the blood in the skin and extremities, and a certain degree of exercise.

It has become much the fashion of late years to expect in the troop horse almost as fine a coat in winter as summer: whether right or wrong we will not stop to inquire; but if it is demanded, I cannot conceive why the common means used in private stables to produce the effect, is denied to the troop horse. It is a well-known fact, that in every regiment there are many horses that have coats in winter of such a thickness and length, that the most laborious grooming will not make them look well; the slightest exercise causes them to sweat profusely; and it takes hours of grooming to dry them. Such horses are always low in condition; but what is of more consequence, they break down the spirits of the men who look after them; and moreover are an eye-sore to the regiment. In such cases I cannot help advising the judicious use of the singeing lamp, feeling assured that the horse would benefit by its

application, both in condition and appearance; and the man would be saved a great deal of unnecessary labour.

Condition of.—There is no term in horse phraseology which bears so many and such widely different constructions as the word 'condition.'

The race-horse is said to be in condition when he can gallop at the top of his speed a given distance without distress or inconvenience to his natural functions,—a state of system brought about by the most artificial, and even unnatural means.

The hunter is declared to be in tip-top condition when he carries his rider a long run, across a heavy country, without failure of wind or muscle.

The coach or post-horse, when he performs the stage allotted to him without sweating,—or other symptoms of over exertion; although every bone in his body might be counted through his skin. The dealer declares his horse to be out of condition while a bone of the ribs can be seen, and until every defect is hidden, as much as possible, by exuberance of flesh and fat.

The London dray-horse is considered out of condition until he represents, as much as possible, the last prize ox at Smithfield; and my lady's carriage horses, to be in condition, must be as sleek and fat as her ladyship's plethoric coachman and butler; and like them, equally unfit for any exertion.

The term condition, as appertaining to horses, can only be understood as relating to the purposes for which they are intended; and we shall therefore, in the present instance, treat of that state of the animal intended to be represented, as the term is applied to the troop horse.

As the pace or severe exertions exacted from the race-horse, or hunter, are not demanded from the troop horse, we do not require for him the same artificial condition to which they are submitted; but as a certain degree of labour is imposed upon him in the performance of military duties, it is not proper or prudent to allow him to attain that state of condition, as applied to dealers' horses. The desirable condition for the troop horse is, a naturally healthy state between the two extremes; not so fleshy as to incapacitate him for moderate exertion, or so poor as to prejudice the symmetrical proportions of his frame.

To bring about this desideratum, the co-operation of several agents is required, the principal being pure air, wholesome food, regular exercise, and proper grooming.

The want of condition is indicated by falling off of flesh, staring coat, frequently attended with hide-bound, or adhesion of the skin to the muscles; and sometimes yellow appearance of the membranes of the nostrils and eyes: when these symptoms are presented, the functions of the stomach and liver are deranged, and the digestive organs generally disordered: worms are frequently the cause of bad condition.

Many medicinal recipes are prescribed for conditioning horses; but the most certain is a proper attention to diet: food easily digested should be given, such as bran, chaff, &c.; and when procurable, green tares or clover; but when these are not to be obtained, oats or barley steeped in water, and allowed to germinate, are a good substitute.

Ventilation.—Impure air and imperfect ventilation produce more diseases among horses than all the other exciting causes of constitutional derangement; nor is it to be wondered at, when we consider that the animal, in his natural state, breathes the purest air of the plains and mountains; culls for his food the freshest and most wholesome herbs; seeks for his drink the most limpid and refreshing streams; exercises himself from the impulse of unerring nature; and recruits his strength by repose impelled only by the dictates of natural necessity;—but view him in his domesticated state,—the slave of man, the living machine of his caprice and pleasure; chained a prisoner in a narrow space, twenty-two hours in every twenty-four; fed

upon dried and fermented provender, according to the whim or means of his owner; worked in some instances beyond his powers of endurance; and in others his functions destroyed by the want of sufficient exercise;—made to breathe air charged with the most loathsome impurities,—and drink water often tainted, and unwholesome; while his very rest is disturbed by the chains of his fellow captives.

All air in stables is more or less impregnated with gases detrimental to the health of the animals; it therefore becomes the duty of those who have the charge of them, to lessen as much as possible the evil consequences arising from their existence. The most unobserving person must have noticed, on entering a close stable, a pungent, irritating sensation, about the eyes and nostrils; frequently sufficiently strong to produce sneezing, weeping of the eyes, and head-ache: these sensations arise from the presence of ammoniacal gas (hartshorn), generated by the fæces and urine. If such effects can be produced upon man in so short a time, who is liable to breathe impure atmosphere, what must be the result of the constant inhaling of these gases upon the tender mucous membranes of an animal which in his natural state breathes the purest gales of Heaven?—the answer is, disease, and even death. The category of diseases produced by impure air are principally inflammatory, and caused by its irritating qualities: of this class are inflamed lungs, influenza, catarrh, chronic cough, glanders, farcy, ophthalmia, blindness, &c. Mr. Youatt, in his valuable work, 'The Horse,' treating of this subject, states—"Mr. Clarke, of Edinburgh, was the first who advocated the use of well-ventilated stables. After him, Professor Coleman established them in the quarters of cavalry troops, and there cannot be a doubt that he saved the Government many thousand pounds every year. At first much evil was predicted; but after a time, diseases that used to dismount whole troops almost entirely disappeared from the army."

A horse consumes in twenty-four hours in respiration, about 100,000 cubic inches of oxygen gas, the vital principle of atmospheric air; and when we consider that frequently eight, and sometimes ten horses, are made to stand in a stable not more than twenty-seven feet square, each horse consuming the same quantity of air, does it not appear imperative that every precaution should be taken to meet the demand? The means to obtain pure air are,—to allow a sufficient quantity of it into the stable; and having apertures so placed as to permit the impure atmosphere to escape; by keeping the stable clean; removing as soon as possible any evacuations; and avoiding any accumulation of manure, or bad litter, in the stable, or near the doors or windows. In badly paved stables, in which the urine lodges between the interstices of the bricks, or stones, great advantage will be derived by occasionally sprinkling the floors with lime, which destroys the generating principle of ammoniacal gas.

Great care should be taken, in making the openings for the purpose of ventilation, that all direct draught or currents of air upon the horses should be avoided. This can easily be done with the upper ventilators, by giving the apertures a slight inclination, from the outside of the stable, towards the ceiling, or roof inside. With the lower openings, or those at the bottom, more difficulties are presented; but a slight glance at the great benefit derived by the admittance of air at the floor of the stable, will stimulate our inventive faculties to overcome them. Air impregnated with ammoniacal gas, which is always found to exist more or less in all occupied stables, from its specific gravity being much lighter than atmospheric air, has a natural tendency to ascend; and where apertures are found to escape, this will be much accelerated, if the partial vacuum caused is supplied by cold and dense air from the lower strata: the supply and escape causing a free ventilation from the bottom to the top of the stable. To avoid a direct current of air upon the horses, which this circulation would naturally cause, I propose that the air be admitted through openings

made in the lower half of the doors, near to the bottom, faced by a piece of flat board, attached to the sides by wedge-shaped pieces; the thinnest end at the bottom. This contrivance will cause the air to be thrown upwards, and prevent any draught upon the horses. The apertures can be closed or opened at discretion, by the application of a piece of wood to form a lid, to work upon hinges, thus, in figs. 1 and 2:

Fig. 1.

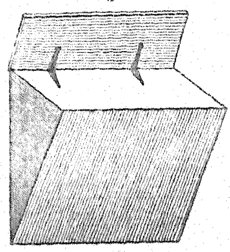
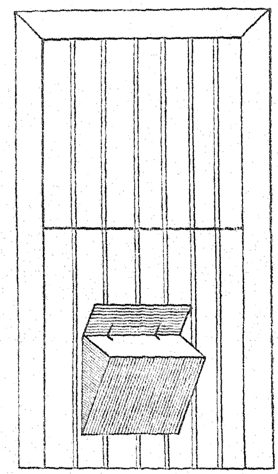


Fig. 2.



There is not much mischief to be apprehended from improper ventilation in the day-time, while the men are constantly opening the stable doors; but at night, when the doors are closed, is the time to observe precaution. The dragoon knows that a hot stable will save him a great deal of labour, by producing a fine coat without much of his assistance; and many a lazy fellow has stolen an opportunity to shut ventilators that have been left open by the non-commissioned officer: such a man, when detected, deserves severe punishment. Generally speaking, the ventilators on the lee-side should never be closed; and in warm weather, all should remain open. Let it be remembered that cold pure air never killed a horse yet, but hot impure air has destroyed thousands.—O. S.

ARTILLERY HORSE.*

In selecting horses for the Artillery Service, the price, although sufficient for procuring such as are useful, will not admit of obtaining such as are remarkable for size and beauty; the former is not desirable from the smallness of the ration on which they are to be fed, and the latter being much a matter of fancy: 3 years old, 15 hands,—4 years old, 15·2,—and 5 years old, 16 hands,—are heights fully ample to admit of sufficient power and action for the purposes required. The average weight of a 5-year old should be about 11 cwt. net, and 80 inches round the chest; and on this weight and measurement may be regulated that of other ages. It must be observed, however, that difference in growth and condition will occasion much variation. The above qualities will then depend on the form and breeding. Rotundity and length in the first will best give weight and power,—the depth from the withers to the brisket should equal that of the brisket to the coronet,—the ribs should arch

* By W. Stockley, Esq., Vet. Surg., Royal Artillery.

from the spine, and descend circular to nearly the line of the brisket, inclining backwards so as to leave but a small space between the back rib and the stifle-joint,—thereby comprising being 'well ribbed up.' The loins should be broad, and somewhat convex,—the shoulder blade should be long and inclining,—the breast light at the points, but broad between the fore legs,—the fore arm long and muscular, with the elbow clear of the chest,—the shank flat and sinewy, filling well the grasp of the hand,—the fetlocks without inclining inwards, or weak, or long,—the feet circular, and somewhat concave on the soles,—the frogs full and elastic,—the quarters should be long from the hip-bones to the buttock points, full of muscle, descending far down the thigh,—the back wide and well defined, and the remainder of the limb having the same qualities as those described before, standing straight, and appearing firm on the ground. The head should be somewhat lean, and the countenance intelligent, with a neck gradually diminishing in size from the shoulders to the head: these latter parts and the quarters, with the tail set on high, more or less, denote the breeding of the animal. The action should be quick, observing that the knee and hock are well advanced, and every limb as nearly as possible in a straight line. Colts, however, occasionally 'dish,' as it is termed, that is, swing their feet: when such is outwards it is of less importance, as it more or less ceases when the powers of their muscles become developed; but when such is inwards, it becomes an insurmountable objection to purchasing: as the age and soundness are within the province of the Veterinary Surgeon, his duties are necessarily defined by his profession, if he knows it.

VETERINARY DIRECTIONS.*

MASSES.—The ordinary dose of every mass is one ounce.

I.—CATHARTIC MASS.

One ounce of this mass made into a ball is a dose of physic.—A ball contains seven drams of aloes, the remaining dram being made up with ol. olivar, ol. carui, and water.

Any horse to whom a dose of physic is given, should be fed on bran mashes, in lieu of corn, until its operation has ceased. If there be no cause for its immediate administration, let ample bran mashes be given, by way of preparation, in lieu both of hay and corn, during one day, and the ball administered the following morning, after the horse is sufficiently watered, and a couple of hours at least before his bran mash be given him. Exercise also, during the day, is advisable. The following day, early in the morning, after the horse has had water with the chill taken off offered him, till he refuses to drink more, let him be walked out briskly for one hour, unless he purge; in which case let him be returned to the stable, littered down, frequently watered, and plentifully supplied with bran mashes. But should the physic not operate at the expiration of his exercise, nor after he has remained four succeeding hours in the stable, let him be exercised for another hour; and he may be gently trotted at this time, should he still shew no signs of purging: let it be here understood, however, that in no case is a horse in physic to be galloped. To insure purgation, water is no less requisite than exercise.

Should the animal continue to purge on the third day, let his bran be eaten dry, and let him be kept short of water and without exercise, until the physic be set. As

* For the Guidance of the Farriers of the Royal Artillery. Suggested by Charles Percival, Veterinary Surgeon; and approved by the Right Honourable the Master-General and Honourable Board of Ordnance.

soon as his dung shall have put on its natural appearance and consistence, the usual ration of provender may be restored, and he may return to duty.

If the horse has been lately taken up from grass, or be low in condition, or light-carcassed, six drams of the mass is generally a sufficient dose; but if he be of large size, and in high condition, even nine drams may be occasionally required.

Horses of a costive habit, whose dung-balls are small and not of their natural colour,—whose coats are rough and skins tight upon their ribs, and who do not thrive, require physic. Purging balls are also given with benefit to horses that have mange, or itchy skins—swelled legs, or grease—fever in the feet—inflamed eyes—staggers—locked-jaw—any swellings from blows or wounds, &c.

When a sick or lame horse requires physic, to whom exercise would be injurious, let the dose be increased by one or two drams; and to him the ball may be given at any time—either day or night—he may stand in need of it; in order that its operation may be as speedy as possible.

To a horse not labouring under active disease, a second dose of physic is not to be administered prior to the seventh day; but to a *sick* one, should the case be urgent, the dose may be repeated at the expiration of twenty-four hours.

Horses suffering from coughs, discharges from the nose, or inflammation of the lungs, are not to have full doses of purgative medicine given them, but the febrifuge or sedative mass should be given.

II.—FEBRIFUGE MASS.

A ball contains aloes one dram, antim. tart. one dram, nitre two drams, and common turpentine three drams.

In fever, also in cough or discharge from the nose in which fever is present, this mass is especially useful; and if the fever be violent, the horse ought to lose three or four quarts of blood before the ball is given. Let the animal be warmly clothed—a hood be worn in catarrh—be littered down, have bran mashes, in lieu of corn, and be kept still and quiet in a well ventilated box. The ball may be administered once or twice a day, according to the symptoms; but it must be discontinued whenever it seems to affect the appetite, or should purging appear to be coming on. The appetite being restored and the dung in balls again, should it be required, the ball may be repeated.

III.—SEDATIVE MASS.

A ball contains—digitalis one scruple, antim. tart. one dram, nitre two drams, linseed meal three drams, and treacle three drams.

In cases of inflammation of the lungs, these balls are especially beneficial—a disease in which colds and coughs not unfrequently terminate. After having drawn four or five, or even six quarts of blood, according to the violence of the symptoms and the apparent strength of the animal, give a sedative ball three times a day at regular intervals. Let the sides of the chest be well rubbed with some of the blistering liquid, clothe warmly, and hand-rub the legs, making use of the turpentine liniment from time to time until they become warm, and bandage them with flannel.—Keep the stable well ventilated.

Should the symptoms continue unabated, four or five quarts more blood must be taken away at the expiration of four or five hours from the first bleeding, and the operation may be repeated again in six, should the animal continue unrelieved.

Let the horse be littered down, and have bran mashes. No exercise.

IV.—DIURETIC MASS.

A ball contains common turpentine half an ounce, nitre two drams, and sulphur two drams.

Diuretic or urine balls may be given in all cases in which they may be required, one every third night; seldom is it necessary to administer one every other night, and still more rarely every night.

Should the flow of urine be abundant—the horse frequently making efforts to stale, and groaning in so doing; or, if he cannot stale, but appear to experience pain about the loins and hips, and to be stiff in moving those parts,—diuretic balls must on no account be given.

Diuretics are beneficial in recent swelled legs; linen bandages and walking exercise being had recourse to at the same time.—They are also useful in watery farcy, dropsy, and puffy or watery swelling of all kinds.

V.—ALTERATIVE MASS.

A ball contains aloes one dram, calomel one scruple, sulphur half an ounce, and treacle three drams.

To ill-conditioned horses that do not thrive, notwithstanding they eat and appear otherwise in health—to horses that rub themselves or that have small lumps or bare places upon the skin, (not mange,)—balls made up of this mass are serviceable: one may be given every day for a week, or every other day for a fortnight, unless the horse should purge, when they are to be omitted, and had recourse to again in the course of a week or ten days.

Bruised corn, hay cut into chaff, and frequent and full supplies of water, contribute to restore such horses to condition.—Walking exercise once or twice a day, according to the strength and thrift of the horse, is also recommended.

VI.—TONIC MASS.

A ball contains blue vitriol one dram, verdigris half a dram, linseed meal four drams, and treacle two drams.

These balls may be administered with advantage to horses affected with farcy or under suspicion of glanders, after the swelling and inflammation attendant upon those diseases have been abated by bleeding, purging, and diuretic medicines.

Not more than one ought to be given in the space of twenty-four hours; nor on any account should the dose be continued unless the horse's appetite is good: as soon as he refuses any part of his provender, or appears to be in any manner affected by the medicine, let the ball be omitted.

VII.—ANTI-SPASMODIC DRAUGHT.

This draught is prepared for horses that become griped, after the following manner: mix together two ounces of spirits of turpentine and one ounce of tincture of opium, and add a pint and a half of warm water.

In mild cases of gripes this single draught will generally suffice, but in violent attacks, four or five quarts of blood ought to be immediately taken away, and the draught after an interval of a couple of hours repeated; also two or three ounces of the turpentine liniment should be well rubbed upon the surface of the belly. If no dung is passed, let the horse be raked, and have clysters of salt and water (about four ounces of salt dissolved in four quarts of water) thrown up every hour until the bowels be relaxed. When the horse continues to lie down and rise in the stall, and

to roll upon his back, relief will frequently be given by walking exercise for ten minutes.

Those cases, in which the symptoms do not intermit, and in which the pulse and breathing are much quickened, are not gripes but *inflammation* of the bowels. Take away five or six quarts of blood without loss of time, and give a draught composed of eight or ten drams of aloes dissolved in a pint and a half of hot water,* with the addition of an ounce of tincture of opium; inject clysters frequently, rub a blister upon the belly, composed of equal parts of oil of turpentine and blistering liquid, wrap the legs in flannel bandages, making use of the turpentine liniment to the legs, if cold, and clothe warmly. Water, with the chill taken off, should be plentifully given; or, what is better, water-gruel.

If the symptoms do not speedily subside, draw three or four quarts of blood again, and repeat the blister to the belly, and clysters and turpentine liniment to the legs, if not warm.

VIII.—VERMIFUGE POWDER.

Three drams of this powder, containing one dram of calomel and two drams of tartarized antimony, form a dose.

To be given in a bran mash at night to a horse having worms, and to be followed up by the administration of a dose of physic the following morning—paying attention to the directions already laid down under the head 'Cathartic Mass.' The powder and physic may be repeated in the course of a week or ten days.

IX.—ANTI-PURGATION POWDER.

This powder is composed of prepared chalk half a pound, cinnamon four ounces, tormentil three ounces, gum arabic three ounces, and long pepper half an ounce, reduced to a fine powder and mixed together, with the addition of gum opium.

An ounce of the powder, which contains only a scruple of gum opium, may be administered in a quart of gruel in cases of continued purging or scouring, every four or five hours, or as circumstances may require, but its use is to be discontinued when the purging is checked.

X.—DISCUTIENT POWDER.

This powder is composed of zinc vitriol three drams, and bole armen. one dram.

A lotion composed of half an ounce of this powder and one quart of water is a proper application to sore backs, and to recent swellings from blows or injuries of any kind.

Bandages may be used, wetted with this lotion, in sprains of the back sinews.

XI.—ASTRINGENT POWDER.

This powder is composed of linseed meal half an ounce, powdered alum half an ounce, blue vitriol half a dram, and bole armen. two drams.

This powder is prepared principally for grease and thrushes; but it is also a good dressing for unhealthy sores—or sores in which there is proud flesh.

In cases of grease, when the discharge is but little, and not very offensive,

* In administering draughts to horses, the greatest possible care and attention is required: should the horse cough, or make an attempt to do so, his head must be instantly lowered, otherwise a portion of the drink will be apt to find its way into the trachea or wind-pipe, which will produce most distressing symptoms, and often be followed by death. In lowering the head, a can or vessel of any kind should be held under the mouth to catch the drink as it escapes.

besprinkle the affected parts with this powder: let the horse be exercised in the morning and afternoon; and if the legs be swollen, let a diuretic ball be occasionally administered.

But should the discharge be copious and fetid, apply to the heels, by means of pledgets of tow and linen bandages, a liniment composed of this powder and oil. This dressing ought to continue undisturbed for two or three days; during which time a dose of physic may be administered with considerable benefit. Let his food consist of bran mashes. As soon as the dressings shall have been removed, the animal ought to be exercised for two hours, the heels afterwards wiped dry, and the liniment again applied, unless the discharge have ceased: in which case the powder sprinkled upon the part, as above recommended, and a diuretic or two, will complete the cure. Should the case require a repetition of the liniment, purging balls are preferable to diuretics.

Of horses that have thrushes, lower the heels, that the frog may be upon a level with the heels of the shoe; pare out the cleft with a small drawing knife, so as to cut away the ragged parts of it, and introduce a little of the astringent powder daily, at the evening stable hour.—If heat be perceptible in the foot, a dose of physic may be given at the same time.

XII.—OPHTHALMIC POWDER.

This powder is composed of sugar lead two drams, turmeric half a dram.

So long as the eyes appear red and angry, nothing but cold water should be made use of to them, with which they ought to be kept continually wet. At the same time, if there be much inflammation, take four or five quarts of blood from that side of the neck corresponding to the affected eye, or from both sides, should both eyes be bad.

When the inflammation is abated, sponge the eyes and eyelids with a lotion, made by dissolving a quarter of an ounce of this powder in a quart of cold spring water, several times in the course of the day.

In every case in which it is found advisable to draw blood, a dose of physic is recommended.

XIII.—BLISTERING LIQUID.

This liquid is composed of cantharides four ounces, and linseed oil a pint and a half.

For sore throat, and *jugged* swellings, in glanders or farcy—for inflammation of the lungs, and inflammation of the bowels, the blistering liquid is a proper application.

For spavins, splints, old strains, curbs, ring-bones, wind-galls, thorough-pins, and other enlargements of joints that have no heat in them, and swellings in general which will not yield to simple remedies, this liquid may likewise be used.

Let a small quantity of it be well rubbed in with the hand—without the hair being cut off—and let the same be repeated at the expiration of six hours, should it not have taken effect.

About one table-spoonful of this mixture is sufficient for the throat, 2 for the leg, 3 for the side of the chest, and so on.

XIV.—TURPENTINE LINIMENT.

This liniment is composed of equal parts of spirits of turpentine and linseed oil.

In cases of sore throat and cough, this liniment will be found very useful, as well as in cases of inflammation of the lungs, and fever, where the legs are cold, making

use at the same time of flannel bandages, and repeating the liniment every two or three hours, until they become warm.

Half an ounce will be found sufficient for a leg, or for the throat, and requires to be well rubbed in.

XV.—TURPENTINE OINTMENT.

It is composed of equal parts of common turpentine and hog's lard.

This ointment is the best application that can be made use of in case of treads or wounds on the coronet, between hair and hoof: a small quantity is to be spread upon a pledget of tow, and bound on with a bandage. It is likewise a good dressing for broken knees or cuts, and to promote the action of rowels.

XVI.—BLACK OIL.

It is composed of olive oil one pint, spirits of turpentine half a pint, and acid vitriol two drams.

In recent wounds, such as broken knees or other lacerated wounds, this will be found a good dressing to promote healthy and speedy granulation. It may be applied to extensive wounds by means of a feather, and in cases of broken knees, a pledget of tow is to be bound on with a tail bandage.

It is likewise a good application for sitfasts, produced by the pressure of the saddle.

XVII.—HOOF OINTMENT.

This ointment is composed of tar and train oil, equal parts.

This ointment is intended for brittle feet, or such as have sand-cracks.

By mixing one part of the ointment with two of train oil, it forms a good application for mange.

HORSE POWER.*

As this is the universal term used to express the capability of first movers of magnitude, it is very essential that the estimate of this power as a dynamical unit should be uniform.

On the Continent of Europe generally, the power of a steam or mechanical horse is estimated upon the original experiments of Watt and Boulton, which assigned to the horse a power of transporting 150 lbs. when travelling at the rate of $2\frac{1}{2}$ miles per hour. This estimate was doubtless in excess, and as it was the interest of the buyer of machinery to increase it, and of the seller to diminish it, as the machine would be respectively equivalent to a less or to a higher horse power, the necessity of reducing a vague estimate into a definite dynamic unit was apparent. Preserving, therefore, Watt's estimate, it was reduced to a dynamic unit as a vapour or mechanical horse power, and stated to be equal to 75 k. m. (*id. est*, kilogramme-metres) per second; or 75 kilogrammes raised one metre per second, or 4500 kilogrammes raised one metre per minute, which is equivalent, in English weights and measures, to 543 lbs. raised one foot per second, or 32,580 lbs. raised one foot per minute. This estimate being generally adopted on the Continent of Europe, it ought to be admitted by English Engineers, or for practical purposes the unit may be taken in round numbers as 33,000 lbs. avoirdupois raised one foot per minute, which is the practice of a majority of our manufacturers of steam engines.

A horse travels 400 yards, at a walk, in $4\frac{1}{2}$ minutes; at a trot, in 2 minutes; at a gallop, in 1 minute.

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* By Lieut.-Colonel Portlock, R.E., F.R.S.

He occupies in the ranks a front of 40 inches, and a depth of 10 feet; in a stall, from $3\frac{1}{2}$ to $4\frac{1}{2}$ feet front; and at picket, 3 feet by 9.

Average weight = 1000 lbs. each.

A horse, carrying a soldier and his equipments (say 225 lbs.), travels 25 miles in a day (8 hours).

A draught horse can draw 1600 lbs. 23 miles a day, carriage included.

In a horse-mill, a horse moves at the rate of 3 feet in a second. The diameter of the track should not be less than 25 feet.

The expense of conveying goods at 3 miles per hour per horse team being 1, the expense at $4\frac{1}{2}$ miles will be 1·33, and so on; the expense being doubled when the speed is $5\frac{1}{2}$ miles per hour.

The strength of a horse is equivalent to that of 5 men.

The unit here adopted as a vapour or mechanical horse power is even somewhat greater than it would have been if strictly calculated on Watt's estimate of 150 lbs., so that it is desirable to ascertain what may be assumed as the dynamic unit in the case of draught, in the actual exhibition of horse power. Mr. Wood, after numerous experiments, reduces the power of traction of a horse to 125 lbs. when moving at the rate of $2\frac{1}{2}$ miles an hour, and supposing his efforts continued for 8 hours in the day —therefore $\frac{2\frac{1}{2}\text{ miles}}{60\text{ minutes}} \times 125 = \frac{13{,}200\text{ feet}}{60} \times 125 = 27{,}500$ lbs. Mr. Wood had previously estimated the powers of traction at 112 lbs., according to which the dynamic unit would be 24,640 lbs.; and others have carried it lower, or nearly equivalent to 22,500 lbs. But it is further desirable to understand the manner in which this principle of a dynamic unit of effective force is carried into practice, as a difficulty is occasionally felt in distinguishing between the actual value of the physical force exercised by a horse and the compound resultant of its operation in draught. It has been stated by M. Regnier, that the extreme effect of a good horse is sufficient to overcome a resistance of 400 kilogrammes, or about 883 lbs.; but this effort could not be continued, and it is therefore necessary to adopt a standard suited to the regular and continued action of the animal—namely, 125 lbs., as given by Mr. Wood. If the weight to be moved be supported, the resistance to be overcome is that of friction, and will be in relation to the nature of the support, thus:

Sledge moving on wooden rails.—Friction 0·70 of weight on first starting, so that the weight which one horse could move with ease would be 167 lbs; but this might be estimated higher, as the friction is less after the sledge has commenced its motion.

A carriage on an iron rail or tram-road.—In this case Mr. Wood estimates the resistance at $8\frac{1}{2}$ lbs. per ton, or about the 264th part of the load: hence the practicable load under such circumstances of a horse is 33,000 lbs., moving as before at the rate of $2\frac{1}{2}$ miles an hour for 8 hours.

A carriage on an ordinary road.—The friction of a common cart, the axles being in proper order, has been estimated at 0·08 of the load: hence the practicable load will be $\frac{125}{\cdot 08} = 1562\frac{1}{2}$ lbs. Mr. Haswell estimates it at 1600 lbs. continued for 23 miles.

If all these numbers be reduced to the same form of dynamic units, they will stand thus:

Vapour or mechanical horse power .			33,000 lbs. av.	moved 1 ft.	per minute.
True traction horse power, at 125 lbs.			27,500 lbs.	"	"
Do.	do.	at 112 lbs.	24,640 lbs.	"	"
Do.	do.	at 100 lbs.	22,000 lbs.	"	"

Draught horse power, sledge and rail, estimated on 125 lbs.	86,740 lbs. av. moved 1 ft. per minute.
Do. carriage and iron rail, estimated on 125 lbs.	7,260,000 lbs. „ „
Do. cart on road, estimated on 125 lbs.	343,750 lbs. „ „

The vapour horse is, however, considered to act continuously for 24 hours, and the traction horse, under any of its applications, only for 8 hours; so that the vapour horse is equivalent to 3·6 traction horses of 125 lbs.—4 of 112 lbs.—or 4·5 of 100 lbs. —to 2·7 draught horse with sledge—to ·013 of ditto with carriage on iron rail—or to ·29 of ditto with cart on road.

Mr. Wood, on the assumption of 125 lbs. moved 20 miles per day at the rate of $2\frac{1}{2}$ miles per hour, and of the friction of carriages on iron railroads being $8\frac{1}{2}$ lbs. per ton, gives nearly 300 tons, conveyed one mile, as the daily performance of a horse. In the following Table, extracted from Mr. Haswell's 'Engineer's and Mechanic's Pocket Book,' a much lower rate of traction force is adopted, viz. 83·3 lbs.; and a day's work of a horse on a railroad is estimated at only 115 tons, working $11\frac{1}{2}$ hours at $2\frac{1}{2}$ miles her hour, which, for 8 hours, would be only 80 tons; so that the friction is here estimated at 21 lbs. per ton. In using the Table for absolute results, these differences must be kept in view; but as regards the relative results at different rates of speed, they need not be noticed.

Table of the Amount of Labour a Horse of average Strength is capable of performing, at different Velocities, on Canals, Railroads, and Turnpike.

Force of traction estimated at 83·3 lbs.

Velocity in miles per hour.	Duration of the day's work.	Useful effect for one day in tons, drawn one mile.		
		On a Canal.	On a Railroad.	On a Turnpike.
Miles.	Hours.	Tons.	Tons.	Tons.
$2\frac{1}{2}$	$11\frac{1}{2}$	520	115	14
3	8	243	92	12
$3\frac{1}{2}$	$5\frac{9}{10}$	153	82	10
4	$4\frac{1}{2}$	102	72	9
5	$2\frac{9}{10}$	52	57	7·2
6	2	30	48	6
7	$1\frac{1}{2}$	19	41	5·1
8	$1\frac{1}{8}$	12·8	36	4·5
9	$\frac{9}{10}$	9·0	32	4·0
10	$\frac{3}{4}$	6·6	28·8	3·6

The actual labour performed by horses is greater, but they are injured by it.

HURDLE.*—Hurdles consist of strong wicker-work of a rectangular form, and are occasionally useful in a siege, or in revetting field-works.

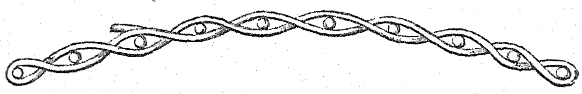
The best size for military purposes is 6 feet long, and 2 feet 9 inches high. The same kind of pickets will therefore answer as in making very strong gabions; and, generally speaking, the rods for hurdles should not be much less than an inch in diameter. An even number of pickets must always be used, and ten is a good proportion for a 6-feet hurdle, although woodmen generally employ only eight for a hurdle of that length.†

* From the Course of Instruction at Chatham.

† The hurdles made by the Kentish woodmen are either 8 feet long, with ten pickets, or 6 feet long, with 8 pickets; and are usually 3 feet high.

In preparing to make a hurdle, it is necessary to describe an arc of a circle on the ground, with a radius of about 8 feet, making the length of the arc 6 feet. This space must be divided into nine equal parts. A picket is then driven into the ground at each end of it, and others into every intermediate point of division, making ten in all. Then the wattling is begun on the same principle nearly as in gabion making, excepting that it is not worked round a circle, but in a continued line; and therefore when it reaches one of the extreme pickets at either end, it must be twisted in the rod like a withe, and be bent round the picket; after which it must be worked in the contrary direction.

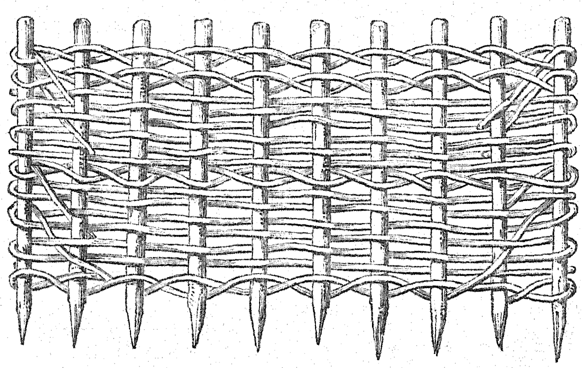
The woodmen assert, that hurdles intended to be straight must always be curved in the first instance, as above directed, in order to prevent them from being crooked, when pulled out of the ground, which they say that those made in a straight line invariably become. And in hurdle making, they use a wooden sleeper, moderately curved, with holes for the pickets on its upper surface, which they lay flush with the level of the ground; but it would not be worth while to make use of such sleepers in the field. The annexed figure is the plan of a hurdle commenced in a curve, according to the above rule.



In commencing a hurdle, the men work from the bottom upwards, as in gabion making, but the first rod is not pressed down close to the ground, excepting in the centre. Both its ends are raised about 9 inches above the ground, and there bent round the extreme pickets by twisting. Thus the first rods used form an arc of a circle, concave on the upper side. The second and third rods are bent round the extreme pickets, as close to the ground as possible, at each end of the hurdle, but in the centre they rise higher than the first rods used; and thus the first three or four rods, or rather courses of rods, composing the web of the hurdle, are interlaced in such a manner, by crossing each other towards the centre, as to prevent the separation of that part of the web from the pickets.

The ends of the rods are kept in their places by pressing against a picket, which jams them, and they are cut off about an inch in rear of it. It is not good workmanship to commence or finish with a rod by cutting it off in this manner, close to either of the extreme pickets, as the twisted joint formed by bending the middle of a rod round those pickets evidently gives greater firmness to the work.

After having been commenced as described, the remainder of the web is worked up



in parallel horizontal courses, until it reaches the top of the pickets: and at this part one or two of the uppermost rods, after being twisted round the extreme pickets, are passed diagonally downwards in an oblique direction, towards the centre of the hurdle, passing through and between one or two of the pickets. This arrangement, which is also sometimes done about half-way up, as well as at the top, prevents the upper part of the web from separating from the pickets. The preceding figure represents a hurdle in elevation, just finished.

In making hurdles for civil purposes, it is usual to work by randing, or with single rods only, for the thick brush-wood generally used in this process is so stiff, that it requires an effort to separate it from the pickets. But as military hurdles would be exposed to greater strains than those used in husbandry, it is better to pair the rods in making them, which may either be done throughout the whole of the web, from the bottom upwards, or at least for several courses at the bottom, middle, and top; for this undoubtedly gives greater firmness to the work. But the precautions before described for interlacing the lowest, and finishing the uppermost courses of the web, render it unnecessary to use vertical withes for binding it, as in gabion making.

NUMBER OF MEN, TOOLS, TIME, AND WEIGHT.

The men and tools to be nearly the same as for gabion making, but with more bill-hooks than knives, and with a line ten feet long.

The probable time for making a 6-feet hurdle would be about three hours; and it weighs about 50 lbs. when the wood is dry.

HUT.*—Huts or Hutting—temporary buildings constructed in haste, materials being available, for Barracks, in preference to placing troops under canvass, when the occupation of the ground may be considered permanent during the wet season; for the worst building which is wind and weather-tight is preferable to a Tent; and the Tent is better than exposure to rain and night dews.

Under the article '*Castrametation*,' some explanation of constructing huts was given, as adapted to circumstances of the moment, when troops found cover for themselves.

Under this head, the Officer is considered to have mechanics to assist him, either as Artificers of the Line or as Sappers and Miners, and that materials are near at hand; and it should be understood that huts have only one story. The following considerations must be borne in mind, in order to give a certain degree of comfort and security against heavy wind and rain.

1. The description and stability of the walls: this latter may be given by great substance in the structure, or by skill in the roofing.
2. The covering, that is, the roof.
3. Economy of space within.
4. Drainage, and selection of site.

It is clear that local advantages must regulate the detail and selection of materials.

I. DESCRIPTION OF HUT.

The stability of the walls is not a question of difficulty, when time and materials can be depended upon, and sufficient workmen. In North America the *log hut* affords warmth and facility of construction. Where timber is abundant but light, the *framed hut*, although requiring more skill, makes a snug dwelling, particularly when lined with bricks. Then we have the *pisé hut*, with walls built in tempered clay; and, lastly, we have *huts built of rubble masonry* with lime or clay mortar.

* Compiled by Colonel Lewis, R. E.

LOG HUT.*

Having been requested to explain the construction of *log huts*, I will accordingly endeavour to attempt a description of such as have fallen under my notice. In a country where timber abounds, as in the Canadas, the settler's first object is to make himself as comfortable as his circumstances will admit of, upon the lot of land destined for his future maintenance and happiness; to do which he usually commences by clearing part of his land of timber, separating the hard wood from the soft: the hard, such as maple, beech, and birch, are usually burnt on the spot, and with the fir and spruce he builds himself a log hut.

Fig. 1.—Plan of a Log Hut, shewing notches A, to receive the next course of Logs.

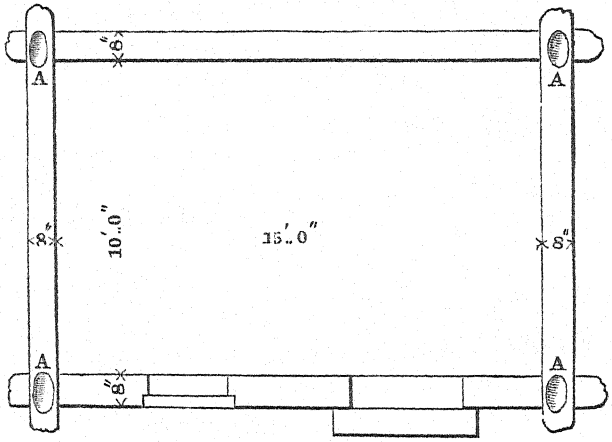
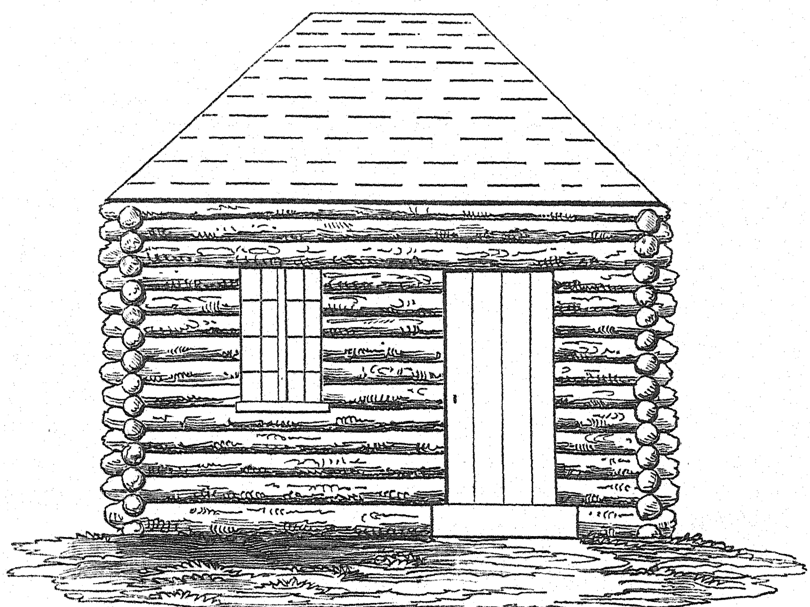


Fig. 2.—Front Elevation.—(Scale 5 feet to 1 inch.)



* By Major Wulff, R. E.

The trees, after being felled, are cut into logs of sufficient lengths to match, and to suit the intended building. I will, however, suppose one according to the accompanying diagrams (figs. 1 and 2), which is the common size usually adopted in a primitive settlement. The bark is generally taken off, and the angle joints are formed by notching (see fig. 1, A, A,) one log half its thickness into the other with an axe, and pinning them together: a projection of a few inches is left in each log at the angles; the logs are thus carried up in courses to the intended height. The joints between the logs are then made weather-tight by a stuffing of clay, or wattles, sallows or small branches of soft wood; and these joints are then lined with laths, or the whole interior boarded, if inch boards can be had, which is preferable.

Fig. 3.—Plan of a Log Hut. Timbers squared and clap-boarded.

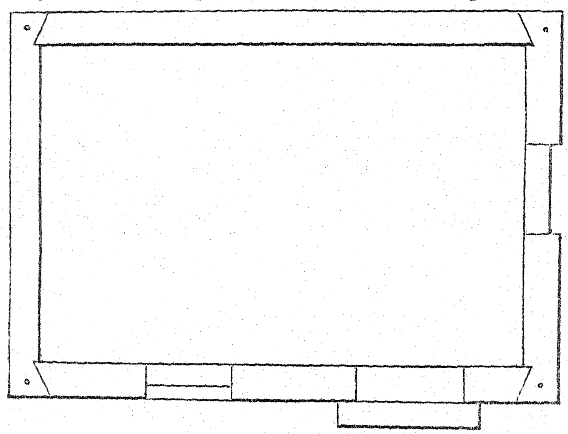
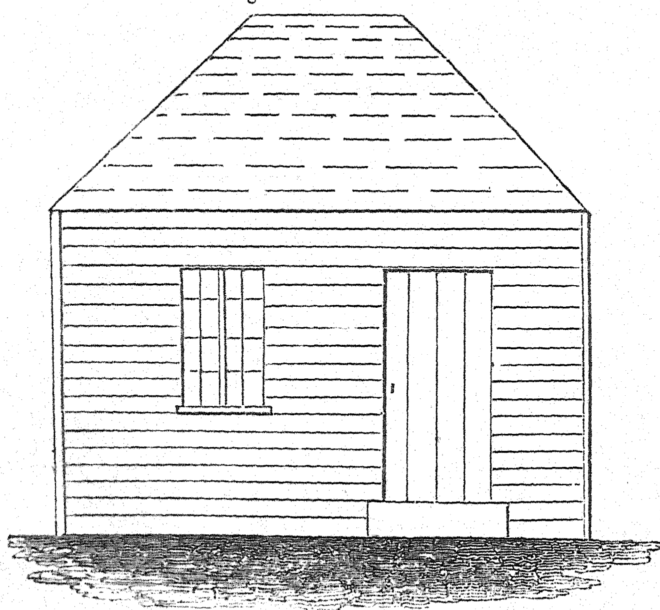


Fig. 4.—Front Elevation.



Scale 5 feet to 1 inch.

Another method of putting the logs together is by squaring them, and making the angle joints either dove-tailed or halved (see fig. 3) into each other, and pinned with wooden pins: this gives a better appearance to the building, and the interior is less exposed to the weather, and it can then receive a better finish both within and without. The outside is then often clap-boarded* (see figs. 3 and 4). It is usual to have a ledged door, and one or two windows, with glazed sashes and shutters. The roof may be framed with scantling of corresponding dimensions to Tredgold's Rules, or even of more slight materials, and covered either with boards to lap over each other, or boards laid flat and shingled; or with laths and shingles; or birch bark.

It is seldom that the poor settler can afford to build a chimney; his only means then left of warming his hut, which is indispensable in such a cold climate as Canada, is by a stove and pipe, the latter passing through the roof, having a clear space of about one foot around it, to receive a piece of sheet iron or block tin, which is let into the wood-work, as a precaution against fire, in case the pipe should become red-hot. A wooden floor is desirable, but in many instances the settler resorts to a cheaper kind, made of the clay or soil on the spot,† mixed with wood ashes obtained from the cleared land, after the timber is burnt off: this mixture makes a tolerably durable terraced floor.

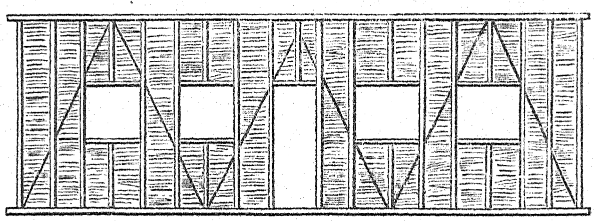
A hut of the former description may be built by two men in about a week, but of course without sashes, or any neat work which requires the more experienced hand of a good carpenter.—H. P. W.

FRAMED HUTS.

Framed Huts with brick-nogging.—One advantage in this description of building consists in the lightness of the material and consequent facility of transport; for the trees may be felled, sawn up, and the scantling prepared on the spot, and no one piece need exceed 11 feet in length × 6″ × 3″ or 6″ × 2″, the mortises and tenons cut, and every piece numbered and designated.

The framed huts must have a ground-sill, say 6″ × 3″ (fig. 7), resting firmly on the ground, well levelled, or, which is better, a foundation of stone, so as to keep the floor 8″ or 10″ above it; on this sill uprights (see fig. 5) are placed about 18″ from each other, of 4″ × 3″, 8 or 10 feet long, which gives the height of the hut: upon the top of these is placed the cap-sill 6″ × 3″ mortised and tenoned, and secured by ties across the building, which prepares the hut for the roof. (See figures 5, 6, and 7.)

Fig. 5.—Brick-Nogging.



The outside of the framed hut is covered with weather-boarding, or, as it is called in the Colonies, clap-boarding, ¾″ stuff, cut with a feather edge; and between the uprights is a lining of bricks, either burnt or unburnt. In carrying up the brick-

* Called weather boards in England.—*Editors.*

† *Vide* Article 'Castrametation.'—*Editors.*

work it is usual to place tie-boards every five or six courses; diagonal braces are necessary to give additional stability, as shewn in fig. 5. The breadth of the hut should not exceed 16′. To simplify the construction, 16′ × 30′ by 10′ high, makes a good barrack-room for 20 men (see fig 7).

Fig. 6.—Weather-Boarding.

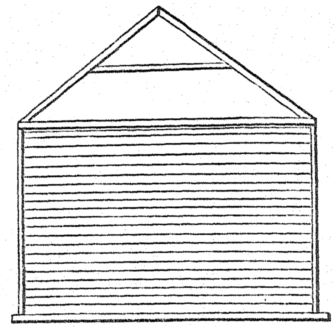
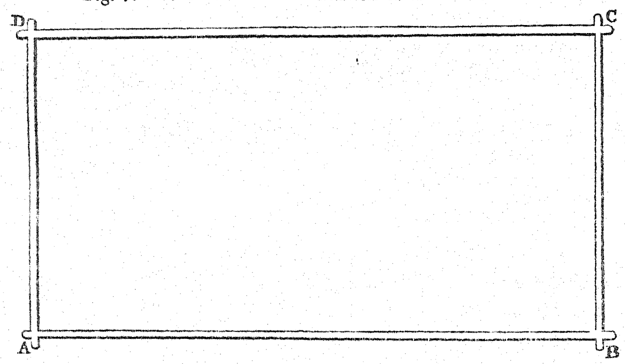


Fig. 7.—Ground-sill for Foundation of Hut.—30′ × 16′.



PISE′ HUTS.

*Pisé Work.**—Within a convenient distance of this spot, another must be fixed upon to supply the earth for the walls of the hut.

But it will be necessary to prove the quality of the earth before proceeding further; and for this purpose the vegetable mould, turf, or whatever the surface may be covered with, should be turned aside; and if the upper part appear sandy and poor, dig a little deeper, and if the quality does not at all improve, try another spot in the same manner; and having found some which has a richer appearance, or if such should fortunately be found on the first trial, it will come up with the spade or pick-axe in lumps: if it have stones amongst it, so much the better; and gravel which has a small portion of clay intermixed, which is known to labourers in England as good binding gravel, will be as good a sort as can be found. Any thing, in short, will do but the poorest dry sandy soil or fat clay, and even these will make very good walls when mixed together, for doing which directions will be given as we proceed.

We must now direct our attention to the mould in which the walls are to be formed, which is very simple, but consists of several parts. We have not given any directions respecting this machine, but it ought to be provided before we arrive at this stage of the proceedings—because it will be better if made by a carpenter, and of seasoned materials, for on this depend not only the appearance but stability of the walls: if well made, there will also be much less trouble and difficulty in fixing it as

* Common in the South of France.

the work proceeds; but it does not follow that because a mould cannot be got which is made by a carpenter, and of the exact size and sort of materials here recommended, that earthen walls cannot be built; but, if made in any other way, the nearer the approach to it, the better will be the condition of the walls. And this remark will apply to every other part of these instructions, which are the best we can advise where they can be acted up to, but which must be altered to suit the circumstances under which they are called into operation. The sides, which are the principal part of the mould, are represented in figs. 8 and 9.

Fig. 8.

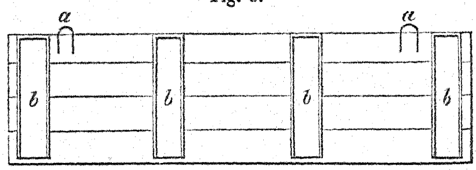
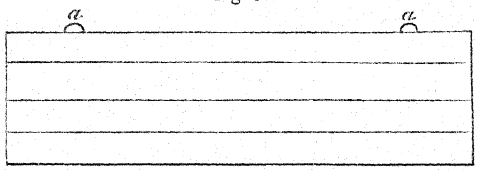


Fig. 8 is the back of one side of the mould, and fig. 9 is the front of the same side. In making each side, take well-seasoned deal boards 10 feet long and ¾ inch thick, with as few knots as possible, and perfectly free from sap, (which shews itself in blue streaks on the sides of such boards,) and as many of them as will make, when finished, 2 feet 9 inches in width (fig. 8 shews four): they should be planed on both sides, and *grooved* and *tongued*, and *ledged*, which means strengthened by pieces nailed or screwed on the back, as shewn by *b b b b*, fig. 8. These ledges, of which there should be four, may be of the same sort of boards, 8 inches wide, and reach from the top to within half an inch from the bottom, where they are sawed off square.

Fig. 9.



The head of the mould is made in the same way as the sides; only one will be required, and of the same width as the intended thickness of the wall, which we shall suppose to be 14 inches. Fig. 10 is the back of it, and fig. 11 the front. When in use, it is kept in its place between the sides by iron pins.

Fig. 10.

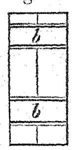
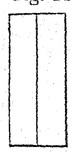


Fig. 11.



The sides of the mould, when fixed, are supported by four bearers or joists lying upon the course, or portion of wall, immediately under the one about to be raised; they are formed of square timber 2 feet 6½ inches long, and in size 3 inches one way, and 3½ inches the other: the part which lies uppermost, when fixed, which is 3 inches wide, is shewn at fig. 12: *a* is the space on which the wall comes; *b b* are notches or grooves into which the sides drop; *c c* are mortises, or holes cut through to the opposite part, 3 inches long and 1 inch wide; and *d d* are the ends left to protect the mortises. The same is seen at fig. 13, in the position in which it lies when the mould is fixed: the several parts being the same in both, the mortises are not to be seen in fig. 13, but their course through the wood is denoted by the dotted lines at *c c*.

Fig. 12.

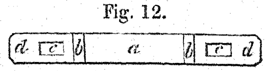
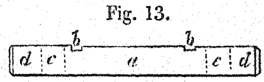


Fig. 13.



The length is thus made up:

	ft.	in.
Space of the wall	1	2
Thickness of the two sides	0	$2\frac{1}{4}$
	0	$2\frac{1}{4}$
Length of the mortises	0	6
Two ends beyond	0	6
	2	$6\frac{1}{2}$

Fig. 14.

Fig. 15.

The upright stays or posts, of which there are eight, are pieces of squared timber of the same width and thickness as bearers, and 4 feet 6 inches long: fig. 14 is the front, or that part which is next to the side of the mould when fixed, and fig. 15 is a side view of the same: the parts at *c c* shew the tenon, that is, a portion at the bottom of the post 4 inches long, from which an inch in thickness is cut away on each side, leaving 1 inch in the middle and half an inch off the back, which causes it to fit into the mortise of the bearers *c c*, at figs. 12 and 13, in which they stand. Thus 4 feet 6 inches, the length or height of each post, half an inch of the tenon, will be seen under the bearer; $3\frac{1}{2}$ inches of the same will be in the mortise, 2 feet $8\frac{1}{2}$ inches will be the height of the side when dropped into the groove, and 1 foot $5\frac{1}{2}$ inches of each post will stand above it.

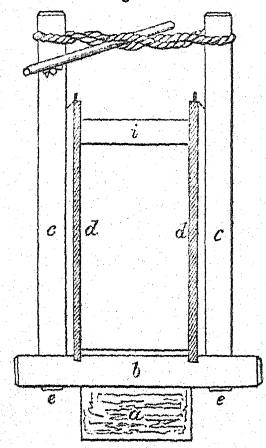
Fig. 16.

Fig. 17.

The struts may be four pieces of wood of almost any description, with the ends sawn off fair, but if they are of the same size as the bearers, it will lessen labour, as will be afterwards pointed out: they are to fit in between and press the upper part of the sides of the mould against the uprights, and thereby give to the wall its proper thickness throughout.

We come now to speak of the rammer or beater with which the earth is rammed in the mould, which is a tool of greater consequence as regards the firmness and durability of the work than would be at first supposed. The form most likely to give the desired effect is shewn at fig. 16, which is the front of the rammer, and fig. 17 is the same seen edgewise. It should be made of oak, walnut, beech, ash, or any other heavy hard wood, and if the butt end could be formed of the root of either of these sorts of wood, it would be the better, because that is always tougher and is less liable to splinter off. According to the form shewn at figs. 16 and 17, it is 4 feet 6 inches long, 5 inches wide, and $2\frac{1}{2}$ inches thick at the butt end, tapering up to the end of the handle, where it is $1\frac{1}{4}$ inch through it.

Fig. 18.



In order to shew the position of the mould and of its different parts when fixed, we have, fig. 18, given a section of it, (that is, the ends or parts which it would present if cut through with a saw), with a part of the underneath course of the wall, *a*; *b*, the bearer, lying upon it, which supports the sides of the mould, and in which the posts or uprights, *c c*, are set and confined at the bottom by the mortises in the bearers at *e e*. A small cord is wound three or four times round both posts near the top, and tied, and by

passing a strong stick through the folds of the cord, and twisting it, it tightens the sides, and if continued, would bring them too close to each other but for the strut (*i*) between the upper part of them, which prevents it: the end of the stick is then brought over a nail or peg in the side of the post, and confined there, which keeps the whole firm and tight together.

The four sides of the hut being now cut out on the outside of the line already marked, and at about 4 inches distant from it, cut a second line all round, which will be the outside of the foundation: dig a trench for the same, measuring from the outer line inwards about 1 foot 10 inches, and about 1 foot deep; but if in a very dry and firm soil, half this depth may do. In the same way mark out the partition wall, and dig a trench uniting with that of the front and back walls. Now although bricks or stone are by far preferable for the foundation, it may so happen that neither are to be got; we therefore pass them for the present, and proceed to shew how they may be done without; and if, as before observed, the soil be dry, and some little precautions, which we shall hereafter recommend, be adopted, the earth which is taken out of the trench, with some of the roughest of that of which the walls are to be made, will do very well.

Having collected some large stones, the larger and rougher the better, throw them, intermixed with a small portion of earth, into the trench, as much as will cover three or four inches at a time; tread it down, and afterwards well ram it, not with the rammers made to work in the moulds, but with rough heavier ones, such as the arm or part of the trunk of a tree. In the same manner fill in and ram for foundation of partition wall. Proceed in this manner till the trench is again filled up even with the ground, and ram well the ground along the edges of the trench, which will be a little broken.

We now return to the earth-heap; and, as was before observed, if the earth be too poor or too rich, it may be made of a proper quality by mixing: this is done by one man throwing up the poor earth in a heap, and another throwing into the same heap a shovel-ful of clayey earth to every two or three or more of the poor earth, according to the proportion which it will bear, and afterwards turning the whole heap over together, and chopping it about well with a shovel. Where it does not require any mixing, it is thrown up in a heap when dug, and the large stones roll to the bottom, and are drawn away with an iron-toothed rake. The teeth of the rake, however, should not be set too close, because stones that are not larger than a hen's egg may be used with advantage. If there are large stones and no small ones in the earth, they may be broken smaller and mixed with the earth. If the earth is dry, it will require a little wetting after it is dug and before it is put into the mould. This simple operation must be done very carefully, as too much wet would render the earth totally unfit for use: instead of suffering compression, it becomes mud in the mould; even though it be a little too moist, it cannot be worked; it swells under the blows of the rammer, and a stroke in one place makes it rise in another, and clay, unless very dry, would do the same; therefore the water should be applied through a watering-pot, or by sprinkling it from a bunch of small boughs, so as not to make the earth in puddles.

In digging the earth, as well as laying it in the mould, take care to pick out every bit of root, great and small, all sprigs and herbs, pieces of hay, chips or shavings of wood, and, in short, every thing that can rot or suffer a change in the earth, because, after a time, such substances will rot, and thereby affect the stability of the wall: very little more should be dug at once than will be used in one day, and, if rain is expected, it should be covered up with boards or any other covering that may be at hand; and the unfinished walls should be protected in like manner.

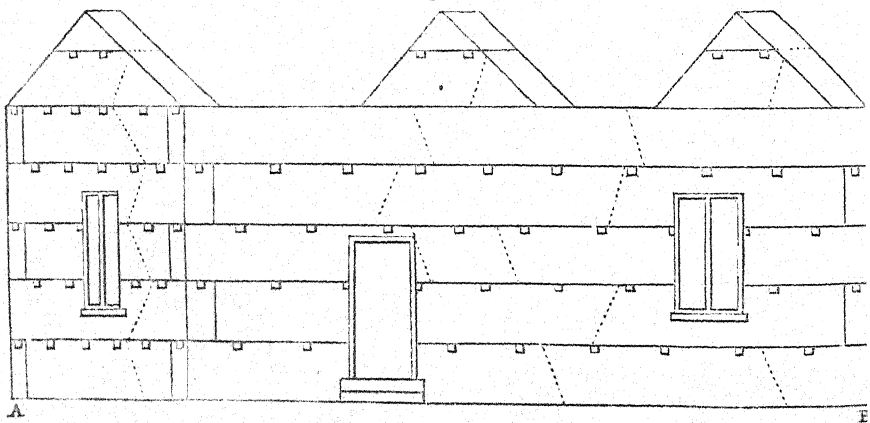
The earth, having undergone this preparation, should be carried to the mould in a basket or otherwise, and strewed over the bottom to the thickness of three or four inches: one man should get into the mould, and spread it even with his feet, and afterwards tread all over it; but he must be careful, in getting in and out of the mould, not to disturb it by blundering against it. It must then be rammed, beginning at the sides, with a rammer such as that shewn at figs. 16 and 17, until the blow leaves hardly any print or impression; and till then add no fresh earth. But as this rammer, from its form, cannot touch the corners, it will be as well to give it a blow, now and then, there, and close along the sides of the mould, with a piece of timber, with the end sawn off perfectly square. For performing this part of the work, there should not be less than two men at the mould and one to supply them with earth; they are placed on opposite sides of the mould, and should cross their strokes particularly under the struts, and both should strike at the same time, so that the earth may be pressed equally in every direction, and care taken in beating against the head of the mould. If the struts were not in the mould, the sides would be slightly pressed towards each other at top by the earth being rammed in the lower part; but as the work proceeds, and the mould is rather more than half full, they will be pressed the contrary way, so that unless the struts are held by something more than the pressure of the sides, they will drop down and may be taken out; but one of them should be applied occasionally to see that the sides do not spread too much, to prevent which the cords must have another twist given to them, which will bring them to.

The head of the mould must be used in forming the angles or corners of the hut, and wherever a course of walling is to be worked against another, a portion of the middle of that which is already built should be cut out slanting upwards, and of the width of one-third of the thickness of the wall, by which means the walls will be more firmly united, and a straight joint through the whole thickness of the wall will be avoided.

To make good walls it is not sufficient that the earths be well beaten, but they must be well united together: to effect this in houses of brick or stone, angles and binders of stone, iron braces, and cramp irons are used, which are very expensive, but here the binders cost very little; they consist only of thin pieces of wood, which are sufficient to give the greatest stability to buildings of this description.

The first course A, fig. 7, being completed, begin the second; and as for the course just finished the mould has been directed from A to B, it must for the second

Fig. 19.



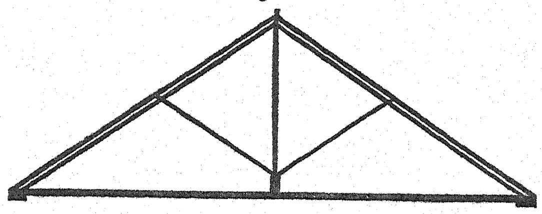
be directed from A to D, fig. 7; that is, in a contrary direction, which will cause the joints in the second course to lean to the right, those of the first course leaning to the left, as seen in fig. 19.

It should be observed, that if the struts are made of the same substance as the joists, a saving of labour might be effected—it is in this way, by laying them in the mould, in the situation which the joists will occupy in the course above, when it is full to within six inches of the top, and continuing to raise the earth on each side of them. When this is not done, the places for the bearers for the next course must be marked out, and small channels cut in the wall to receive them; but as this will jar and unsettle the work in some measure, it is better avoided. Before this second course is begun, a board about 5 or 6 feet long should be laid at the bottom of the mould, resting on the angle A, and extending lengthwise towards B, fig. 19: this board must be rough from the saw-pit, not more than 1 inch thick, and in breadth from 4 to 9 inches, according to the thickness of the wall, so that there may remain on each side of it not less than 4 inches of earth: by this means the board will be entirely concealed in the body of the wall, and when thus placed, neither the air nor damp can reach it, and of course there is no danger of its rotting. This board, from the pressure of the work raised above it, will contribute to bind together the two lengths A and D, fig. 7. Put in a similar binder to each of the angles, and also where the courses of the partition wall join to those of the exterior wall: the directions given for the second course must also be observed at each succeeding course up to the roof. By these means a great number of holders or binders will be formed, which sometimes draw to the right, sometimes to the left of the angles, and which powerfully unite the outer walls as well as the partitions; the several parts deriving mutual support from each other, and the whole being rendered compact and solid. Hence these huts, made of earth alone, are able to resist the violence of high winds, storms, and tempests.

RUBBLE MASONRY.

Rubble-masonry Huts, built of masonry in irregular courses, without faces or any dressing, when stone, should be selected of materials of moderate depth, and with even surface or bedding. Stone of 3, 4, and 5, and not exceeding 6 inches thickness, is frequently met on the surface in horizontal layers or beds, easily detached, and adapted to the thickness of the walls required for the hut. Rubble walls should be from 20 to 24 inches in thickness, laid in clay or lime mortar: the latter of course gives a greater durability to the structure. The principal care in this nature of building should be in laying the quoins or exterior angles, and to the doors or windows, and in carrying up the work horizontally upon a good solid foundation. For the description of stone necessary, and which is frequently found on the surface, see 'Stone, Building;' for it is not contemplated in the construction of huts to quarry stone. In the event of such being the case, see article 'Quarrying.'

Fig. 20.



30 feet.

Huts constructed of *pisé-work*, or *rubble masonry*, will bear a framed roof, and a heavy covering of tiles, slates, stone or brick. The preceding diagram will explain the nature and size of the timber necessary in framed roofs for hutting.

Table of Scantling for Framed Roofs.

Span.	Tie-beams.	King-posts.	Principals.	Struts.
Feet.	Inches.	Inches.	Inches.	Inches.
16	8 × 3	3 × 3	4 × 3	3 × 3
20	9 × 4	4 × 4	4 × 4	4 × 4
25	10 × 5	5 × 5	5 × 5	5 × 5
30	11 × 6	6 × 6	6 × 6	6 × 6

II. ROOFING.

Covering or Roofing of Huts is perhaps the chief difficulty where mechanics are scarce and unskilful, and the choice of materials limited: the usual resources for hutting are *Thatch*, *Shingles*, *Paper*, or *Felt*, where lightness is an object; and flat stones, bricks, and tiles, if the walls are sufficiently substantial, and care be taken in the construction of the roof.

Thatch, the easiest and generally most available, but objectionable on account of fire, may be obtained from low grounds, in the shape of reeds, rushes, and long grass; and in tropical climates, the plantain leaf and other vegetation of the like nature. Thatching is performed in the following manner when straw can be procured; but reeds and rushes and long coarse grass can be used by previously making them into bundles.

Thatching is a name given to a kind of covering over roofs: it is generally made of wheaten straw, laid on lathing and rafters, which may be of the same strength and placed the same distance apart as for a common slated roof; but in country places where thatching is mostly used, the rafters are generally formed of the branches of trees of from 3 to 6 inches in diameter: the slighter they are the better, provided they are sufficiently strong, as the lighter the roof is, the less strain there is on the walls: of course, if the rafters are stout, they should be placed farther apart than slight rafters; and if the rafters are far apart, the lathing must be stronger, otherwise the thatching will bag, or lay in hollows between the rafters.

The straw is laid on the lathing in small bundles called 'hellams,' until it attains a thickness of from 12 to 16 inches; it is fastened to the rafters with young twigs and rope-yarn in a manner hereafter described.

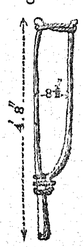
A good pitch for a Thatched Roof is 45°, or, as it is technically called, a 'true pitch:' if the pitch is made less, the rain will not run off freely; and if a greater pitch than 45° is used, the straw is found to slip down from its fastenings.

A Description of the Uses of the Thatcher's Tools.

The Thatcher's Tools are—

A common stable fork.—This tool is used to toss the straw up together when it is wetted, preparatory to its being made into bundles for use.

Fig. 21.



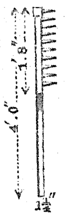
A thatcher's fork, (fig. 21.)—This is a branch of some tough kind of wood, cut with two smaller branches proceeding from it, so as to form a fork, as shewn in the diagram: the joint of the two branches is generally strengthened by a small cord, to keep it from slipping when it is used. A small cord is fastened by one end into one of the ends of the fork, and a loop is spliced on the other end of the cord: this loop is made to

pass over the other end of the fork, and to fit into a notch cut to receive it, as shewn in the diagram.

This tool is used to carry the straw from the heap, where it has been wetted and prepared, up to the thatcher on the roof, where it is to be used.

A thatcher's rake, (figs. 22, 23, 24.)—The handle should be of ash or some tough wood, made not round but square, so that it may be grasped firmly without

Thatcher's Rake.
Fig. 22.



Back of Rake.
Fig. 23.

Section of Rake.
Fig. 24.

fear of its slipping round in the hand: the arrises may be slightly rounded off, so as not to hurt the hand. It will be seen by referring to fig. 23 that a crook is formed in the handle; the reason for this will be explained when we come to speak of the manner of using the different tools.

The use of this tool is after the straw is laid, to comb it down straight and smooth.

A thatcher's knife, or *eaves' knife*.—This tool is similar in shape and make to the reap-hook, except that it is larger, and not curved so quickly.

The use of this tool is to cut and trim the straw to a straight line at the eaves of the roof.

The thatcher also requires a knife shaped something like a bill-hook, to point the twigs used for securing the straw.

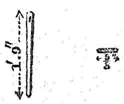
A half glove or mitten, of stout leather, to protect the hand when driving in the smaller twigs, called spars.

A long flat needle, (fig. 25.)

A pair of leather gaiters, to come up above the knees, to protect his knees and shins when kneeling on the rafters.

A soft grit-stone, to sharpen the knives.

Thatcher's Needle.
Fig. 25. Section.



The Timbering and Lathing necessary for a Thatched Roof.

As before stated, the rafters for a thatched roof may be of round timber, such as the branches of trees, *and young trees*, of from 3 inches to 6 inches in diameter, placed not more than 14 inches from centre to centre, but sometimes the rafters are of sawn timber: in that case they should be cut about the same scantling as for a slated roof, not as for a tiled roof.

The lathing in a thatched roof being very liable to rot, it should be split out of heart of oak, or some other equally durable wood: the laths are about 1¼″ wide, and ¼″ to ⅜″ thick, and are nailed on the rafters about 8 inches apart in an horizontal direction, just the same as for a tiled or slated roof.

If the laths are placed further apart than 8 inches, the straw is apt to bag or sink down between them; the rain lodges in the hollows, and of course soon rots the straw.

An eaves' board about 7 inches wide is required to start the first part of each course of thatching upon.

A Description of the Manner of executing a Thatched Roof.

The rafters and eaves' board being fixed, and the lathing nailed on in rows at the prescribed distance apart before mentioned,—

As much straw is taken as it is thought will be required for the whole roof, which may be got at by estimating a square to take from $4\frac{1}{4}$ to $4\frac{3}{4}$ cwts. of wheaten straw: care should be taken to keep the fibres or stalks as parallel to each other as possible. As each truss of straw is opened, it is spread out and wetted, using about 3 or 4 gallons of water to each truss: the straw is then tossed over and mixed together in one great heap with the stable fork, so that every part may get an equal portion of the water. If the weather is fine and dry, the straw may be used directly; but if the weather is damp or rainy, the straw should be allowed to lay for a day or so to drain, and be once more turned over.

The reason for wetting the straw is to make it lay close, and to enable the thatcher's labourer more easily to draw the stalks out parallel.

The thatcher and his labourer being now ready to commence, the labourer spreads as much of the straw on the floor as will make a bundle 12 inches wide and 4 inches thick: the labourer then stooping down, with his left hand he draws the straw, little by little, to his feet, and while doing so, he with his right hand draws out any loose straws that may be lying crosswise: by this means he gets a compact bundle of straw from 3 to 4 feet long, according to the goodness of the straw, and all the stalks are parallel. This bundle is called a 'hellam.' The labourer having placed 4 or 6 hellams crosswise in his thatching fork, he carries it on his shoulder up to the thatcher on the roof, in the same manner as a bricklayer's labourer carries a hod of mortar: the fork is secured on the roof by a small peg and a piece of string.

The thatching is now laid in courses 3·0 wide, beginning at the right end of the roof, so that the thatcher works from right to left. The courses are laid parallel with the rafters, and not parallel with the lathing (as is the case in slating and tiling). Care must be taken at starting at the eaves to have a good firm body of thatch, letting the straw hang over, to be afterwards trimmed with the eaves' knife to a straight and good-looking edge. A row of three hellams is placed on each succeeding lath in the course, and each row of hellams is secured to the rafters with a young tough twig, called a ledger; it is about 4 feet long and an inch in diameter: each row of hellams is also secured to the row underneath it with three split twigs, called spars: the spars are about 2 feet long, and eight can be split out of a branch 2 inches in diameter; they are pointed at both ends, and are then doubled in two, and the thatcher gives them two twists round in his hand, in the same manner as a rope is twisted: this gives the spar a splintery surface, and enables it to hold on when driven into the straw.

The thatcher has a leather glove on his right hand; and keeping his hand flat or open, he gives the spar two or three smart blows, sufficient to drive it into the straw, and the leather serves as a protection to the hand. The spars must be soaked in water for some hours before they are used, in order that they should not break in the doubling up.

The *ledger* is a tough twig, about 4·0 long and 1 inch thick, as before described: one end is pointed, and driven or rather pushed 6″ under the outside* rafter of the course: it is then brought over the top of two rafters, and over the top of the

* In speaking of the outside and inside rafter of a course, it is meant by the outside rafter, the rafter that is farthest from the thatcher; and by the inside rafter, the one that is nearest to him; and thus the inside rafter of one course becomes the outside rafter of the next course.

hellams, and then secured to the inside rafter of the course with about 8 feet of rope-yarn, by means of the long flat needle, thus holding down the row of hellams, and preventing them from slipping off the roof.

The thatcher gives each course, as it is laid, a combing down with his rake, to get out the loose straws: he then takes a bucket of water, and throws it right down the course, and gives the straw a good beating with the back of his rake, to break any stubborn straws and to make it all lay close: he then finally gives it another combing, and after that smooths it down with the back or flat side of his rake, and it is finished.

It will be seen by referring to figs. 22 and 24, that a crook is formed in the handle of the rake. The reason for thus crooking the handle is to keep the thatcher's hand from contact with the straw, and thereby save his knuckles.

The ridge and hips are managed thus. The thatcher, in doing one side of his roof, takes care to leave a good length of straw hanging over and past the ridge. As he finishes the top of each course on the other side of the roof, he bends down the tops of the first side, and covers them over with the last row of hellams on the last side, bending these last in their turn down over the other side of the roof.

The ridge is then secured on each side with three rows of bands or spars, placed end to end, and each spar is secured with three other spars to thatch.

In the case of the hips, there are no 'bands' of spars, but single spars, 12 inches apart, are bent crosswise over the hip, and secured with three other spars, as before. The eaves are also secured with two rows or 'bands' of spars.

Where the side of a roof is high and much exposed to the wind, the whole ledgement is secured with these 'bands' of spars.

To repair a thatched roof, the old thatch is left on; and another thickness of from 8 to 12 inches is laid on the top of it, the whole being done in just the same manner as described for a new roof, except that no ledgers are used. The greatest practical difficulty in thatching is in joining one course on another so that there shall be no gutter between them; in fact, to do it in such a manner that the joints of the courses cannot be observed.

The way the thatcher manages is this: he lifts up the edge of his last course, and inserts the edge of the succeeding one under it; and then beats and smooths them down as even as possible. If care is not observed in doing this, six or twelve months will shew bad workmanship—hollows like gutters will be seen at the joints of every course, and the water will penetrate into the underneath straw, and will rot it much before its time.

Miscellaneous Information concerning Thatching.

Wheaten straw thatching, done as here described, will last in our climate from fifteen to twenty years.—Oat straw, about eight years.

In the West of England (where the best thatching is done), they have a superior kind, called 'reed-thatching:' the ears of the wheat are cut off, *not thrashed out* in the truss: the truss is then wetted, and carefully spread out on a table, and one end is secured or held down by a board with a weight on it: the thatcher combs out all loose flags or broken straws, leaving only the clean sound pipe straw. To make a roof with this, the roof is first thatched in the common way, and then a thickness of 3 inches is laid on with spars only.

Shingles, or wooden slates, are made from hard wood, either of oak, larch, or cedar, or any material that will split easily. Their dimensions are usually 6 inches wide by 12 or 18 inches long, and about ½″ thick. They are laid in courses of 4 or 5 inches,

nailed upon boards, the joints broken, laid in horizontal courses, commencing with the eave course. The ridge is secured by what is called a ridge-board, or a triangle of inch stuff of 6 or 8 inches each side. In America, where this roof is common, the mechanics have a special tool for shingling, called a shingle-axe, with a hammer at the back.

Paper and Felt are sometimes available, as likewise *Canvass*, which are nailed by scupper-nails, and then tarred over.

Flat Stones of light materials, and *Bricks*, laid flat in good lime mortar, and then covered with a good coat of plaster, will answer when the walls and roof are very substantial, so as to bear the weight without cracking the mortar. Framed roofs should be constructed according to fig. 20.

Tiles are an excellent resource where clay is at hand, and there are people sufficiently skilful to make them; but the manufacture of tiles is difficult, and the burning or baking much more so. Tiles may be manufactured either as *plane-tiles*, *pan-tiles*, *Italian tiles*, *ledger-tiles*, and *gutter-tiles*. The first, as the most simple of construction, is recommended.

Plane-Tiles are made of clay, afterwards dried and burnt in a kiln, and as their name implies, are perfectly flat: they are in size $10\frac{1}{2}$ inches by $6\frac{1}{4}$, and $\frac{5}{8}$ths thick; two holes are formed in the upper end by the mould, through which are driven wooden pegs of about $2\frac{1}{2}$ inches long, by which they are hung upon the laths. Strong laths of oak or fir are nailed across the rafters, upon which the tiles are hung by the pegs. In tiled or thatched buildings the whole ends of the rafters generally pitch upon the plate, and in that case pieces are nailed upon them, called rafters' feet, and at the lower end of these is fixed the eaves' board, which is a piece about 5 inches wide and 1 inch thick at the lower edge, and tapering off to the upper edge: the tiles, &c., project over this, and are laid either with or without mortar in the same order as slates: where mortar is used, the whole of the tiles are not pegged, but in the other case they must be. Tiles resist both heat and cold much better than slates, but are inferior to slates in most other respects: slates being cheaper, lighter, better in appearance, and more durable; and consequently none but buildings of an inferior description are now covered with tiles in England.

III. ACCOMMODATION.

Economy of space and internal arrangements will depend upon the skill of the workmen and the materials that can be obtained within a moderate distance. If glass cannot be procured, and most of the houses out of the large towns in the South of Europe and in South Africa are unglazed, *shutters* must be provided; consequently the windows should be small, and at least 4 feet above the floor, so as not to interfere with the sleeping places. A common ledge door is sufficient for a hut, and such fastenings as the smith can make or be got near. Except perhaps in the Tropics, every Barrack-room should have a fire-place: it serves for ventilation as well as for drying the men's clothes. Floors of the simplest materials only can be afforded, in clay or rough paving in brick or stone; but the men under every circumstance should have their beds above the floor. It has been found, without reference to construction or the size of the hut, that the half-billet trestle used in Ireland is an excellent resource for want of the iron bedstead, and the soldier is kept a few inches off the ground, and secured against the damp. These trestles are inexpensive, easy of construction and conveyance: they are made of *two-inch boards*, 8 inches broad by 6′ 6″ long, battened together like a ledge door (see fig. 8): they are laid upon blocks of wood 6 or 8 inches square, placed head and foot, and the elasticity of the boards renders this construction a comfortable and a healthy bedstead.

It is not usual to plaster or ceil Soldiers' Huts: the Officers' rooms should be, if possible, floored and ceiled. The Hut, 16 feet by 30 feet, as shewn in fig. 7, may be divided into two good Officers' quarters, and adopting these dimensions in hutting gives one uniform construction which will simplify the execution of the work.

IV. SITE.

Drainage and Site.—Every hut should be well drained, and the water carried away from the foundations, but the ground in the vicinity should be levelled and adjusted, to prevent water collecting. Hence every care should be taken that there are means for draining, and that the site should be sufficiently elevated to permit the water to be drained off freely. Except in the Tropics, the entrance of every hut, where possible, should face the mid-day sun, and the back of the hut turned from the prevailing winds. The floor should be at least 8 inches above the level of the ground; and where building stone and masons are to be had, then huts should have a foundation of 18 or 20 inches high.

In the selection of a site for hutting a Detachment or a Regiment, water and fuel should be as near as possible, more especially water.

For Troop and Artillery horses it is usual to leave one side of the hut, facing the mid-day sun, entirely open, and racks and mangers are not provided; and the back wall must be sufficiently strong to bear the pull and jerking of the horses' heads. In very bleak places, the front or open part may be closed in at night with bushes or tops of trees, to break off the wind.

Mr. Cresy* observes "that the simplest construction employed is undoubtedly with roofs in an excavation made out of the solid rock or earth. Trees pitched one against the other in a triangular form (see fig. 26), and well secured at the base,

Fig. 26.

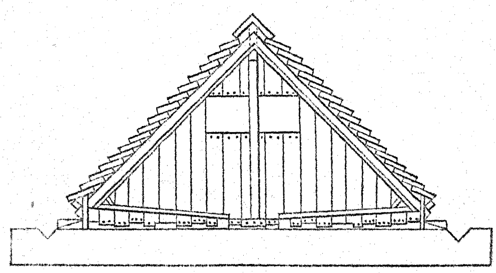
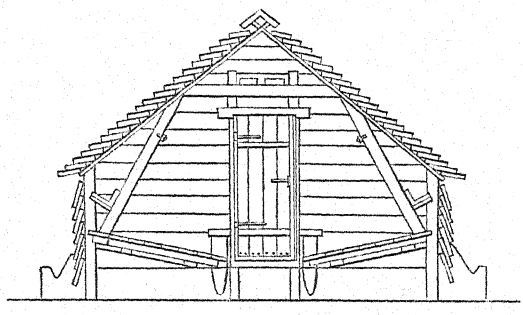


Fig. 27.



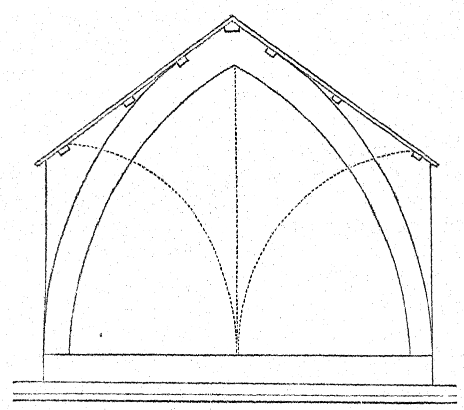
* See 'Encyclopædia of Civil Engineering.'

would serve as rafters, which would support either branches, shingles, or pieces of wood laid one over the other, to keep out the weather: upright boarding or palisading to close the gables or ends, would then constitute it a rude dwelling.

"An improvement upon the above method would be that of raising the roof sufficiently above the ground to enable the inhabitants to walk erect beneath it. (See fig. 27).

"In some of the ancient works on carpentry we have designs for primitive huts with the principals curved or set out like the pointed arch, or with the ribs of a whale, so placed that they are made to carry the weight of a roof, as shewn in fig. 28.

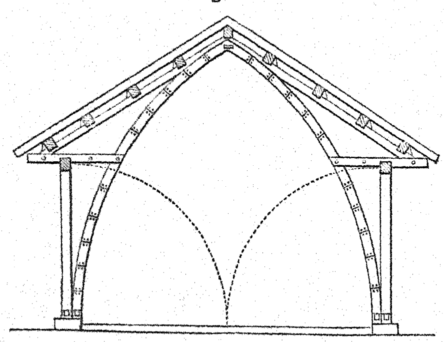
Fig. 28.



"The roof is that portion of a building which requires the greatest degree of skill, and where the aid of science is more essential than any other.

"Buildings are sometimes found rudely braced by curved ribs, and which bear a resemblance to a boat turned upwards: these ribs are occasionally made by nailing or pinning together short lengths of thin deal, and securing the plate on which the roof pitches to their sides: rafters laid with a slight projection to throw off the water, and a number of purlins resting on them in a horizontal direction, require nothing more than the tile, slate, or metal covering to complete the roof," (fig. 29.)

Fig. 29.



ON THE MANUFACTURE AND CHOICE OF BRICKS.

Every one is so familiar with the general qualities of brick, that it is almost needless to say it is a sort of artificial stone, composed either of pure clay or a mixture of coal ashes, and, in some cases, an addition of chalk to loam or clayey earth, which, after undergoing preparation, is tempered with water, formed in a mould, and dried in the sun; and afterwards, in most cases, baked or burned in a kiln, or in a clamp. The antiquity of bricks is also well known, the invention of them being carried by some even beyond the deluge; but we have indubitable proof of the use of them, as well as the principle on which they are made at the present time, being known at as early a period as the building of the city of Babel by the descendants of Noah; for we are told that on their commencing that great work, "they said one to another, Go to, let us make brick, and burn them throughly; and they had brick for stone, and slime had they for mortar:" thus has the art of making bricks been carried through a period of four thousand years, almost without variation. The latter process in the art, that of burning, has been at times dispensed with, as it is at this day in some parts, in which case a quantity of straw is intermixed with the clay to give the brick additional tenacity. Bricks made in this manner, however, will not bear exposure to the weather, or fire.

There is and ever has been considerable variation in the size of the brick. The Romans,—who were so bountifully supplied with marble and stone, that bricks were but little used in building till towards the decline of the republic—made them chiefly of large dimensions, and the relics of them preserved by the antiquary prove them to have been much the same in quality as our best kiln-burned ware. We have no information of the precise date at which the art of burning bricks in a clamp was introduced: the discovery and introduction of the use of coal, which is necessary to their composition, is comparatively recent—but that of applying it in the manufacture of bricks is much more recent, and indeed may be said to be modern; for clamp-burned bricks, or *grey-stocks*, as they are called, did not make their appearance till the latter end of the last century, and were not brought into general use till the beginning of the present. They have, however, attained such a state of perfection, as far as building is concerned, that they have driven their flaming rivals out of the field wherever a choice existed.

The earth selected for brick-making should be clay of the purest kind, but where that is not to be found, an inferior quality may be made use of, provided it be free from stones.

In England, bricks are chiefly made either of stiff clay, or of a yellowish-coloured fat earth, commonly called *loam*. The former produces the red bricks, which are burned in a kiln; the latter—which is the sort found near London and in the adjoining counties—when burned in a clamp, makes a neat yellow or grey-coloured brick. The quality of each sort as to hardness and fineness of grain, as well as colour, is varied considerably by the natural qualities of the earth, or by an artificial process which it is made to undergo.

Bricks are applied to various other purposes as well as for building, and these are manufactured where the clay is found which best adapts them for their several uses. We need only notice two of these, and that but slightly, which are paving-bricks and fire-bricks. The former, as is well known, are used for paving the floors of cottages and out-houses; they are made of various sizes, and are very hard and brittle, being made of clay in its pure state. Fire-bricks are used for building or lining the inside of furnaces, or such buildings as are exposed to a continual live heat, which some of this ware will resist more effectually than iron.

Building bricks, as before observed, are of two sorts: kiln-burned, which are of a red colour, and clamp-burned, which are grey, and are called grey-stocks. It will be as well for the reader to impress these terms on his memory, as we shall, in alluding to them in future, call the former *kiln-bricks*, and the latter *grey-stocks.*

The earth, of whatever quality, for making bricks, should be dug in the autumn, and laid in a heap till the spring, so that it may have the benefit of the winter's frosts,* which by mellowing it, greatly improves its quality, and otherwise assists the labours of the brickmaker. As the process in making kiln-bricks is most simple, we shall for the present confine ourselves to them, and afterwards point out the difference between them and the grey-stocks; and here we would observe, that the light earths generally contain such a quantity of sand as to render the management of them very difficult: on the other hand, some of the stronger clays are improved and rendered more serviceable by the addition of a portion of sand,† which lessens shrinking and prevents cracking in burning.

Previous to beginning to dig the earth, the turf or upper surface of the ground should be pared off as great a space as may be required, and as much of the ground under it removed as is unfit for the purposes of brick-making, and laid aside: another space, a little below this, should also be cleared and made even, on which the brick earth is to be laid as it is dug, and formed into a regular square heap of about 2 feet deep, which the workmen gauge by sticking notched sticks in the ground, and in this state it is left through the winter. Early in the spring, if the earth is of a nature to require the addition of sand, it is spread equally over the top of the heap, and in such proportion as the case requires.

As soon as the danger to be apprehended from frosts is gone by, which in England is generally about the latter end of March, brick-making is commenced. The brickmaker or *moulder* having set up his gear, consisting of a temporary shed near the heap, of a very rude construction, being merely four posts set in the ground, and a hurdle or two with straw run between the splints for a shelter laid upon the top, and having a rough table under it, at which the bricks are moulded; between the heap and this shed, the clay-mill, or *pug-mill,* as it is called, is fixed, which is made in the manner of a cask with staves and hoops, and rather wider at bottom than top —about 5 feet long, and 3 feet wide at the bottom,—an iron spindle runs down the middle, working in a socket at bottom, and passing through an eye at top, where it has a beam attached as a shaft for a horse, by which it is turned. From the sides of this spindle strike five or six iron arms in different directions, and in these are fixed iron blades also in different directions, which, by repeated divisions, thoroughly intermix the earth, which is put in at top, by the time it reaches the bottom, where it is forced out at a hole in the side,—a much less tedious method of preparing the earth than the old practice of kneading or treading it, though some will have it not so good an one: a common barrow to convey the earth from the heap to the *pug-mill,* and two *off-bearing barrows*, which, instead of the box or body of the common barrow, have a light frame with a flat lattice top, about 3 feet high over the wheel, and 18 inches near the handles, so as to be about level when in work, on which the bricks are laid in rows to be conveyed to the *hacks.*

The *hack ground* is laid out between the moulding shed and the kiln, or place intended for the clamp, and if there be a slight fall of the ground towards the latter, the better: slight elevations in straight rows are then formed, about 2 feet wide, and at a distance of about 5 feet from each other, for the *hacks*, which are the piles of bricks set up in their green state to dry, the surface of the raised parts being made perfectly

* In cold climates.—*Editors.*

† Also to harden and even vitrify the bricks.—*Editors.*

even: a little fine earth or sand is sifted over them, as well as over the track between for the off-bearing barrow, which should run smoothly, or it will injure the newly formed bricks. The brick *mould*, which should be made by a skilful person, and with precision, is composed of iron or steel, but as it requires to be very light, the sides are strengthened by thin pieces of well-seasoned wood, over the edges of which the iron sides are turned and finished square; it must be somewhat larger than the intended size of the brick, to allow for the shrinking in drying and burning. The table being furnished with brick boards, a raised block with iron edges is laid on the moulding table to receive the mould; and a quantity of fine sand, and all things being in readiness, the labourer, whose business it is to supply the clay-mill, chops down a quantity of brick earth with a shovel or hoe, and turns it well over to intermix the several parts, adding a little water in the operation, if necessary; then filling his barrow, he wheels it up a strong plank laid for that purpose towards the pug-mill, and shoots the contents in at the top, which he continues to do throughout the day. The horse being put in motion, works it down the mill and through the hole at the bottom, where it is cut off by a boy with an iron instrument, having a handle like a shovel, and carried to the moulder's table. It is here received by another boy or girl sitting on the right of the moulder, who draws off with the hands a piece rather more than sufficient to fill the mould, and works it into the shape of the mould, and it is then rolled towards the moulder, who takes it up in both hands, and dashes it into the mould, thereby filling up every part of it. He then takes in his right hand, from a bowl of water fixed in front of his table, a *strike*, which is a thin smooth piece of wood, and drawing it along the edges of the mould, strikes off the overplus, or as much as lies above the edges, which he throws back to the assistant on his right, to be again moulded. He then turns the mould over and turns out the brick upon one of the brick boards, which he sets on a double iron rail at his left, along which they are slid by a boy who afterwards places them on the *off-bearing barrow:* at the left-hand front corner of the table is the dry sand into which the moulder every time dips the mould, and dashes the inside well, to prevent the brick from sticking. The bricks being laid each upon a brick board, are set upon the barrow, and after having some dry sand sifted over them, are taken away by the *off-bearer*, who is next in importance to the moulder; for if the bricks are moulded ever so well, an unskilful person, by handling them while green, would soon spoil the shape. Having arrived at that part of the ground where they are to be set, he commences the *hack*, in doing which he takes a loose *brick board* and places it on the upper side of one of the bricks, removes it between the two boards to its place on the ground, setting it on its edge and drawing the boards gently away: he then lays one of the boards on the barrow, and with the other proceeds as before till he has deposited the whole, when he returns with the barrow and boards, and another load is ready for him. In this way the hacks are set up two bricks in width, not straight across, but diagonally or in a slanting position, and tolerably close: after the bottom row is completed, another *hack* is begun, because when the brick is just moulded it will not bear the weight of another laid on the top of it; when the bricks have *set*, or become sufficiently hard to bear the weight, they are piled one upon the other, generally to the height of eight bricks. After the bricks have stood in close order a few days, they are reversed and set more open, which allows the wind to pass freely, the bottom bricks being put at the top and the top ones at the bottom: a sufficient quantity of long straw, rye being the best, and wheat next for the purpose, is provided and laid alongside the hacks, and at night is laid gently on the top, and is then left till the weather is fine enough to allow of its being removed: some who make bricks on a small scale have small sheds erected,

covered with boards or thatch, under which the hacks are set; but the advantage of the sun's rays falling upon the bricks is sacrificed in such cases. The time allowed for drying the bricks will vary very considerably with the weather and other circumstances; but when they appear to be dry, they should be proved by breaking through the middle one of them in different parts of the field, and they must not be put into the kiln until they are as dry at the centre as on the outside, or the heat, when applied, will cause them to fly to pieces.

The kiln is of various forms, and brick-built, having only one aperture in the sides. If made in the oblong form, which is the most simple, and to burn 20,000 bricks at a time, it should be about 14 feet long and 10 wide, and the walls not less than three bricks thick, and a little inclined towards each other as they go up. Flat arches are turned near the bottom, with spaces left at regular intervals resembling lattice-work, through which the fire ascends. The bricks are set upon these arches sufficiently open at the bottom to allow the fire to pass, and closer at the top, where they are covered with old brick or tile rubbish, to keep the heat in; this being done, some wood is put in and kindled, to dry them thoroughly: when this is done, which is ascertained by the smoke having become more transparent, the mouth of the kiln is stopped up with old bricks plastered over with clay or brick earth, only just room enough for a fagot being left, and the burning is commenced by putting in fagots of brush-wood, furze, heath, &c.: the fire being thus made up, is continued till the arches assume a whitish appearance, and the flames appear through the top of the kiln, upon which the fire is slackened, and the kiln cools by degrees. This process is continued, alternately heating and slackening till the bricks are properly burned, which is generally in the space of forty-eight hours. Very great precaution is necessary in thoroughly drying the walls of a new kiln with a gentle heat before the full power of the fire is used, or they will be sure to burst, whatever may be their thickness: this gradual drying is also necessary for the same reason in other works, such as ovens, or wherever a powerful heat is employed.

The process of making grey-stocks differs very materially from that of kiln-bricks. The earth is dug at the same time and in a similar manner, but the earths employed in making them generally contain a quantity of sand, therefore there will be no occasion to add more; but earths containing too much should not be used, or the bricks will be very unsound, or what the workmen call *shaky* or *shuffy*, lying in flakes like a thick pie-crust; and, when struck against each other, will make a dull rattling noise. This is the case with most kiln-bricks as well as inferior grey-stocks, but the best grey-stocks are as firm as a rock, and will, when struck, give out a clear ringing sound. In place, however, of the sand, a layer of coal or cinder ashes is laid over the brick earth, which is afterwards intermixed, first by the labourer, and then by the pug-mill. It is also prepared and moulded in the manner before described, with the exception of the sand employed by the moulder; this for kiln-bricks is such as is used to sift over the floors in public houses, and kitchens of country houses, and may be either red or white, provided it be of sufficient fineness, and such is generally to be found in the vicinity of a brick-kiln. Not so for the grey-stocks; the only sand of which we have heard of being used with them is procured from the side of the Thames at low water near Woolwich; hence called Thames sand, which has a fine silvery grain, is free from grit, and of a greenish white colour. With these exceptions, the process is the same up to the period of burning bricks, but for the clamp they require to be more uniformly dry than for the kiln, because in the clamp the whole force of the fire is applied at once, and continued. The ground upon which the clamp is to be set is raised and made perfectly level, and covered with

old bricks set on their edges: on these are set the new bricks, with a flue or space of about 9 inches wide and 3 feet high left up the middle from end to end, to contain the fuel: if the clamp be large, as many of these are left as may be required. Small openings are also left between the bricks at the bottom part of the clamp, for the deposit of the cinders used for fuel, called *breeze:** the flues are not arched over, but the bricks are overset gradually till they meet, or nearly so, at the top; layers of breeze are laid occasionally between the layers of bricks, and the *breeze* is laid thickest towards the outside of the clamp, which causes the bricks on all sides to lean slightly towards the centre: the bricks in the upper part of the clamp are set closer than those in the lower part, as they receive a great portion of heat from underneath, and do not require so much *breeze* to be distributed amongst them. When the new bricks are put in the clamp, the top is covered with dry earth or turves, and the outside is cased with old slack-burnt bricks, called *place-bricks;* a few of these are also intermixed in the clamp. The fire is then applied to the wood in the flues, and as soon as it makes sufficient progress, the ends are stopped up with old bricks, and plastered over with clay, and the fire spreading in all directions, the clamp soon becomes one solid mass of fire, being fed by the ashes contained in the bricks themselves, as well as by the layers of breeze between them. While in this state it should be carefully watched, as in windy weather the draft will carry the fire entirely to one side: this is to be prevented by setting boards or hurdles, with straw or reeds interwoven between the splints, against the side on which the wind blows.

The quantity of fuel to be used can only be ascertained by practice, as it differs very materially in different soils, and also in the quality of the *breeze*, which is merely cinders collected with the ashes in London and other places: these are left behind when the ashes are screened, and very often contain a great deal of unprofitable rubbish. The quality and quantity of the ashes used in making the bricks is also a consideration; for if these be good, each brick is, as it were, a fire-ball, containing material within itself sufficient not only to retain, but to increase the heat applied to it from without. If there be a deficiency in either of these cases, the bricks, instead of being hard and sound, and of an uniform yellowish grey colour, will be very tender and of a pale red colour, and of course will not bear exposure to the weather for any length of time. But although by using too small a portion of fuel the bricks are rendered of a very inferior quality, the other extreme, that of employing too much fuel, is not the less dangerous, for in that case the intense heat causes the bricks to vitrify or run together like melted glass; and when taken out of the clamp, twenty or thirty are sometimes cemented together: in this way they have the appearance of a mass of black rock, and are quite as hard.

Every clamp produces a greater or less quantity of each of these inferior descriptions, the plain bricks near the outside, and the others in the centre over the flues; but an experienced moulder, by whom the clamp is erected, knows how to reduce it to the lowest possible amount. The place-bricks are used for internal walls and other purposes, where strength is not an object, and are sold at nearly one-fourth less price than stocks.

The masses of over-burnt bricks are called *burs;* and such of them as it is found impossible to separate with an iron crow-bar are sold by the cart load for rough foundations, or to form cascades, or ornamental rock-work, in gentlemen's pleasure grounds, for which they are very appropriate.

The grey-stock, when properly manufactured, has a decided preference over the

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* When coals are not to be had, *brush-wood, furze,* and *timber* will serve every purpose for hutting troops.—*Editors.*

kiln-brick, being, in most cases, more durable, less porous, and of a much more agreeable colour.*

The kiln-brick may be said to be baked rather than burnt; and, like most other baked substances, is crusted over the outside, and not of equal hardness throughout. It is extremely difficult even for an experienced man to detect this inferiority; for whether well or ill burnt or baked, there is very little variation in the colours and outward appearances of them; but after being a few years exposed to the weather, the outer shell will drop off, and the remainder, on losing its protection, will speedily decay. It may be said that there are kiln-bricks as durable, in every way as well adapted for building purposes, as the best grey-stocks; and we in a great measure agree with the assertion, but at the same time wish to point out the danger of giving the preference to kiln-bricks, when it is almost impossible to detect the inferior ones from the sound ones, the appearance of both being so much alike.

There are certain methods of preparing earths by washing the common earths and adding chalk thereto, by which the colour is varied from a deep gold yellow to a very pale yellow, almost white; but our limits will not allow us to give a detail of the process. These colours are obtained without mixture in some earths, but they are much more rare than the common sort.

These bricks are termed *marls* or *malms*, and are again divided into *rubbers*, *pickings*, and *seconds:* the first are used for rubbed arches over windows and doors, and similar ornamental work, being cut with a brick-axe, and afterwards rubbed on a grit-stone. Some of the finer sorts of kiln-bricks are also used for the like purposes.

ON THE PROPERTIES, USES, AND MANUFACTURE OF LIME.

It is not intended to enter into a chemical investigation of the nature and properties of lime; but as a knowledge of the leading principles is so necessary to a perfect understanding of the subject, we detail such facts as we deem most useful, endeavouring at the same time to render them as plain and intelligible as possible.

Lime is prepared, for the purposes of building, by calcining or burning with a red heat, in a kiln properly formed, such substances as chalk and most of the varieties of stone and marble.

The whole of these substances in the natural state, whether chalk, stone, or marble, are called *limestone.* The fixed air which this contains is termed *carbonic acid.* ~~It is~~ the lime that is used in building ~~which has been~~ must be deprived of its fixed air by being burned. Thus the perfection of lime prepared for building purposes consists principally in being deprived of its carbonic acid, most of which is carried off during the process of calcination, in the form of gas or steam.

It was the opinion of the ancients, and is still partially received among our modern builders, that the hardest limestone furnishes the best lime for mortar; but experiments have proved it to be a mistake, and that the softest chalk-lime, if thoroughly burned, is equally durable with the hardest stone-lime, or even marble lime. But although stone and chalk-lime are equally good under this condition, there is a very important practical difference between them, which is this: the chalk-lime absorbs carbonic acid with much greater avidity, which reduces it to powder, and if it be only partially burned, will, on the application of water, fall into a coarse powder, which stone-lime will not do.

Limestone loses nearly half its weight by burning; and if properly burned, it is more than doubled in quantity or bulk when *slacked*, that is, when reduced to powder by pouring water upon it.

For making mortar, the lime should be used as soon as possible after being taken

* In hutting troops, the colour of the bricks, and whether they are burnt in kilns or clamps, is of no importance.—*Editors.*

from the kiln; for if left long after exposed to the air, it will separate, first into small lumps, then into a fine powder, and in this state will make but a very inferior mortar, because it has already again absorbed as much carbonic acid as it can possibly contain, and consequently, when made up into mortar, it has not the power to absorb any more.

There is a difference of opinion among practical men as to the proportions of lime and sand to be used in making mortar; that of three measures of sand to one of lime being most approved, provided the ingredients be good and well beaten. Qualities, however, will differ in degree; therefore the best guide will be to use no more lime than will be sufficient to surround the particles of sand, and give the mass the necessary degree of plasticity, or, as workmen would say, make it hang together.

Mortar in which sand predominates requires less water in preparing, and therefore *sets* sooner: it is harder and less liable to crack in drying, for this reason, that lime mixed with water shrinks in drying, while sand retains its original magnitude.

The best mortar for dry building is thus prepared: Take well-burned lime fresh from the kiln, in which state it is called *quick-lime*, strew any quantity at a time, say a bushel, on a stone floor, and pour water equally over the whole till it is saturated, or will absorb no more; turn it up in a heap with a shovel, when it will crack and snap, and steam will begin to issue from it; cover the heap over with clean sharp sand, say three bushels, taken from the bed of a running stream, or washed in clear water through a sieve, which will confine the steam and heat; proceed in like manner with the remainder, and then let it rest for a time. In this state it generates a powerful heat, which it keeps up long enough to cook a joint of meat by. This method of cooking is sometimes resorted to by workmen when the heap is large, in which case they enclose the meat in a tin box or a cloth, to keep it clean; and although the heat is not of an inflammable nature, it may be made to communicate fire to wood or other light substances, through the agency of iron: thus a quantity of quick-lime being slacked and turned up against a boarded fence or building, will set fire to the same through the agency of the nails, which will be rendered red-hot, or nearly so, by the heat of the lime. During this time, the decomposition of the lime is going on: when it is completed, the heat begins to subside, and the lime is reduced to an impalpable powder, and is in this state called *slacked-lime.* It is then turned over with a shovel so as to mix the lime and sand well together, and sifted or screened: the parts left behind, being pieces of limestone which have passed through the kiln unburnt, or partially so, are called *lime-core*, and should be thrown aside. If a superior mortar is required, it is afterwards beaten with a wooden beater upon the stone floor. When it is required for plastering, a quantity of hair from the hides of bullocks is stirred in and mixed with the mortar, by means of a double-pronged hook, like a hay-fork, with the tines or prongs turned downwards.

The hardness which good mortar attains soon after being used, is said to be the effect of crystalization.

Shells are sometimes calcined, and afford a lime which will make a very good mortar. Mortar made of this lime *sets* or becomes hard quicker than that made of common limestone.

Lime-kilns are built of different forms or shapes, according to the manner in which they are to be wrought, and the kinds of fuel to be employed.

The rudest and most ancient kind of lime-kiln is probably that made by excavating the earth in the form of a cone, of the size required, and afterwards building up the sides or not, according to the circumstances of the case. The materials being then laid in alternate layers of fuel and limestone, properly broken, till the whole is filled up, the top is covered with sods (thence termed a *sod-kiln*), in order that the heat

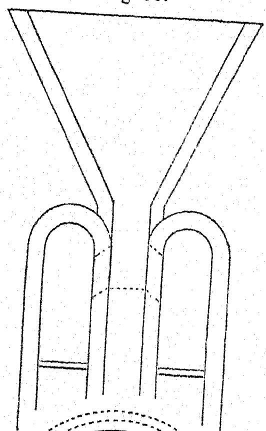
may be prevented from escaping, and the fire lighted at the bottom. The whole of the contents are burnt in a greater or less space of time, in proportion to the nature of the limestone and fuel, and the quantity that is contained in the kiln. When the contents are cold, the lime is drawn or taken out from the bottom, and the kiln is filled again, if necessary. Burning in this way, although it may be found most convenient in some situations where lime is only occasionally wanted, and in small quantities, is not to be recommended when other means can be adopted, as it is both tedious and uneconomical.

Where lime is much wanted, they therefore use *perpetual* or *draw-kilns* built of stone or brick; the latter is preferable, as being better adapted for standing an excessive degree of heat.

Burning with peat is sometimes practised, and, considering the rude and ill-constructed kilns which are used for the purpose, it is astonishing with what success the operation is performed. It is stated that limestone is sufficiently calcined by placing it with alternate layers of peat, in kilns formed of turf; but owing to the quantity of ashes which fall from the peat, the quality of the lime is considerably deteriorated, and from the open and exposed situation of most of them, the waste of fuel is immense.

An economical method is practised with effect in many parts of the country which are situated at a great distance from coal, in kilns somewhat similar to the brick-kiln, and from furze and similar fuel being used in them, called *flame-kilns*. The walls are built of brick, and should not be less than from 4 to 5 feet thick when not supported by a mound or bank of earth, and built battering or diminishing upwards: the dimensions inside 13 feet by 12 feet, and 12 feet high, or thereabouts. In the front wall there are three arches, each about 1 foot 10 inches wide and 3 feet 9 inches high. When the kiln is to be filled, three arches are formed of the largest pieces of limestone, with one end adjoining and open to the arches in the front wall, and running the whole length of the kiln to the opposite side. When these arches are formed, the limestone is thrown promiscuously into the kiln above the arches to the height of 7 or 8 feet, over which are frequently laid 15,000 or 20,000 bricks, which are burned at the same time with the limestone. When the filling of the kiln is completed, the three arches in the front wall are filled up with bricks almost to the top, room being left in each sufficient only for putting in the furze, or other fuel, which is done in small quantities, the object being to keep up a constant and regular flame. In the space of about forty hours, the whole of the limestone, about 120 or 130 quarters, together with 15,000 or 20,000 bricks, are thoroughly burned.

Fig. 30.



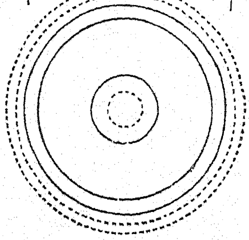


Fig. 31.

We need not repeat the caution respecting the thoroughly drying the walls of such kilns by a continued and gentle heat before the full heat is employed in them.

The form of lime-kiln found most advantageous is that of an inverted cone.

We here give a section (fig. 30) and plan (fig. 31) of a lime-kiln of this description, which is built of

brick, and in the following manner: The spot fixed upon should be near to the limestone pit; a circular hole must be dug in the earth about 12 feet diameter at top, and rather narrower at the bottom, and when the top of the kiln is to be even with the surface of the ground, about 14 feet in depth. The foundation is laid and carried up as a circular solid base, to the height of 3 feet, when it is built hollow, and two or more *eyes* or draft-holes are left, 1 foot 6 inches high by 9 inches wide. At the distance of 2 feet 6 inches from this base another wall is built, forming a passage round it, which is called the chamber, and has a small doorway in front, or at that side from which the lime can most conveniently be taken out. When the walls and base are carried up to a sufficient height from the floor of the chamber, an arch is turned over it, and the conical part of the kiln commences, which is 18 inches at the bottom, and expands as it goes up till it has spread out to the diameter of 8 feet at the top. The bricks selected for the purpose should be such as will best stand the fire, and laid with a thin joint of very good mortar. Moveable gratings are fixed in the draft-holes, to keep the lime in till drawn. Iron plates, or blowers, as they are called, are also fitted to them, to regulate the draft. The outward door is generally an open one, to allow a free passage to the air, very little lime being kept in the chamber, as it is not drawn till the cart arrives to take it away. When the situation of the kiln will not allow of the ground being sloped down to the door of the kiln, steps are formed part of the way up, and a wing-wall is built on each side, to keep up the ground. As soon as the mortar is set, the ground should be filled in, and well rammed up to the sides of the kiln as the work proceeds.

In describing the way in which the process of burning is carried on, we would be understood as speaking more particularly of the lime made from chalk, although our remarks will in most cases apply to stone-lime also.

The chalk for making lime is dug from a bank or cliff, or in a pit sunk through the upper strata in the earth, whence it is drawn up in buckets by means of an axle and wheel; the latter method being in general attended with most trouble. The large lumps are brought in barrows or baskets, and laid in heaps round the kiln. The *lime-burner* having in his right hand an instrument like a small pick-axe, beginning at the end of one of the heaps, chops the lumps into the requisite size, (about the size of a man's fist,) and sitting across that which is already chopped, he continues chopping, drawing it towards him and advancing till he gets to the end of it. If there be much small chalk, as is sometimes the case, it is separated by sifting, and thrown aside. Supposing the fire to have been extinguished, he proceeds to light it by laying a quantity of wood and large coal at the bottom of the kiln; over this is laid a layer of limestone, and then another of small coal; fire is then put to the fuel, and another layer of chalk added: when the fuel in the lower part of the kiln is nearly consumed, a hollow space is formed below, and the surface is united or caked together, which the *lime-burner* breaks up with a large poker made of wood, and pointed with iron, like a pike, and long enough to enable him to reach the bottom of the kiln with, when standing upon the top.

As to the lime hanging to the sides of the kiln, it will be supposed that the surface of the kiln, after being exposed for some time to a continual red heat, will not be very smooth; on the contrary, it is thereby rendered very uneven, and the coal lying in contact with it in the course of its decomposition by the fire, unites itself and hangs to this rough surface as it would to any other of a similar material, without reference to its form or shape. It is to prevent the ill effects which might ensue from this circumstance, as well as to give full effect to the fire, that the lime-burner is provided with his long poker; and if he make proper use of it by breaking

up the surface of the mass, and disengaging it round the sides occasionally, as well as before drawing off the lime, the object will be fully answered.

When the lime is thoroughly burned, it drops down into the bottom of the kiln; and when a sufficient quantity is there collected, the grating is removed from one or other of the draft-holes, through which the lime rolls and falls upon the floor of the chamber, and the grating is returned to its place. Every time after breaking up the surface of the limestone in the kiln, a thin layer of small coal is strewed over the surface, then another layer of limestone, and so on; the number of layers and quantity in each being regulated by the quantity of lime in demand in a kiln of the above dimensions: this may vary from 10 to 140 bushels per day, but if it be ever so trifling, it is advisable to keep the fire always in, if possible, as when it is once let out, it is not properly got up again without a great loss of time and fuel.

A kiln of this description produced lime of a very good quality, and fit for any of the ordinary purposes of building, on an average of 400 bushels per week; and at the rate of three and a half bushels of lime to one of small coal, the fire was never let out but once a year,—that in the midst of winter, for about a week, and not even then when there was the least demand for lime, which happened to be the case in two or three instances.

In burning, it is necessary to keep the fire up at a regular red heat, and not to make it too powerful, or it will cause the lime to vitrify, and the surface of the lumps being thereby covered with a glazed coating, will be rendered useless.

The coal * used is small, almost dust, and passed through a screen to give it uniformity: a shed should be provided for it, to keep it dry, and as near the kiln as may be found convenient. If a shed or some such shelter were erected for the limestone also, it would be found advantageous; for when taken from the pit, even in the dryest weather, it contains some moisture, but in rainy seasons, in consequence of lying round the kiln in small heaps, it is often completely saturated with wet before it is put in the kiln, which causes an otherwise unnecessary quantity of fuel to be expended upon it. Breeze, such as is used for burning clamp-bricks, is also, by some, used in burning lime, either alone or mixed with small coal.

I.

ICE.†—The action of frost has often rendered useless obstacles ordinarily of great value for defence: the capture of the Dutch fleet by the French artillery crossing the Zuyder Zee on the ice, in 1795, and the storming of Bergen-op-Zoom by the British troops crossing its wet ditches when frozen over, are among the most recent instances of this; and the disaster of the French at the Beregina, in 1812, is a proof of its power of *impeding* the passage of rivers: it is therefore of the utmost importance in warfare to foresee its effects, whether in rendering muddy roads, and even marshes or lakes, as firm as the best pavement, or in making rivers impassable by filling them with loose ice, or ice too thin to bear troops.

The *thickness* of ice required for supporting infantry in files is about 2 inches; for cavalry and light guns 4 inches; and for heavy carriages not less than 6 inches: the latter should always be kept as far apart as possible: also, if 8 inches thick, 24-

* Brush-wood, furze, timber, and turf or sod, answer sufficiently well for the purposes of hutting.—*Editors.*

† By Captain Bainbrigge, R. E.

pounder guns on sleighs may pass over it, or any load not causing a greater pressure than 1000 lbs. per square foot on the surface, covered by the runners or skids on which it moves:* and if the ice is weak, they may have baulks secured by lashings to the tires of the wheels, for them to slide upon, so as to spread the weight over a larger surface, or lines of planks should be laid down for them to pass over.

Weak ice may be made capable of bearing even artillery in a very short time during frost, by spreading upon it layers of straw or brushwood crossing each other, and sprinkling them with water, so as to form a solid road when frozen; and if any portion of the river remains unfrozen from the rapidity of the current, it may be made to freeze by mooring trees and brushwood so as to float in it.

When the ice is too thin for walking upon it, a man may often skate over it, which is also the most rapid mode of conveying information over ice; and ice-boats, similar to those used in Canada, might also be used for this purpose: they consist of a slight frame supported on three skates or runners, one of which serves as a rudder, and, provided with masts and sails, they tack like a ship with great rapidity directly to windward, and attain a velocity of twenty miles an hour with a fair wind.

Floating ice is very liable to destroy bridges; and its effects in rubbing against the piers, when propelled by a strong current, are amazing, tearing off the smallest projecting portions, even if of iron: to resist this, *ice-breakers* in front of the piers are indispensable; they consist of a frame supported on two rows of piles meeting each other, and forming a small angle against the current: the upper surface should be planked over, and should slope upwards from the water's edge towards the top of the pier, so that the floating ice may rise over it, and thus break itself up, so as to pass harmlessly between the piers, which, if of piles or trestles, should be carefully planked over, to prevent the ice catching in them.

To *cross rivers* full of floating ice, very strong boats or canoes, cut out of entire trees, are required to resist the pressure; they may be dragged over the floes (even if in motion), which are too solid to admit of breaking canals through them.

To open a communication through fixed ice, or to destroy that in the ditches of fortifications, strong barges (if possible, moved by screw-propellers) are required; their bows must be well protected with iron plates, and they should be provided with heavy beams, to be raised by ropes and let fall upon the ice in front: saws may also be used if the ice is very solid, having heavy weights attached to the end under water, and the pieces of ice, when detached, can be hauled out of the water by means of ropes.

In the defence of fortifications during frost, canals, 15 feet wide at least, should be kept open along the centre of the ice covering the wet ditches, by keeping boats constantly moving along them: the earthen slopes may be rendered slippery also by pouring water over them, so as to cover them with a coating of ice.

Small barriers of ice, or the *keys* of barriers interrupting the navigation, or causing an inundation, may be destroyed by turning streams of water against certain points, so as to melt an opening, or by means of charges of powder in casks or bags, fixed underneath or lodged in holes bored in the ice, and fired simultaneously: a charge of 6 lbs., placed in the centre of ice 2 feet thick, will break it up into small pieces throughout a circle of 10 feet radius.

Ice and snow, well rammed together, form temporary parapets capable of even more resistance against shot than those of earth.—P. J. B.

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* This is proved by the details relative to the transport of a 24-pounder gun over ice by the American artillery, published by the Committee of the Royal Artillery Institution, Woolwich, March, 1846.

K.

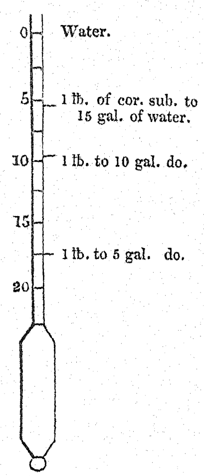
KYANIZING AND BURNETTIZING.*—KYANIZING is a simple process by means of which timber, canvass, and cordage, &c., may be preserved from the effect of dry-rot, and seasoned in a very short time. It was invented by Mr. Kyan, who obtained a patent for it, which was purchased by a Company called the 'Anti-Dry-rot Company,' constituted and empowered by Act of Parliament.

The timber is prepared as follows:† a wooden tank is put together so that no metal of any kind can come in contact with the solution when the tank is charged.

The solution consists of corrosive sublimate and water, in the proportion of 1 lb. of corrosive sublimate to 10 gallons of water, as a maximum strength, and 1 lb. to 15 gallons as a minimum, according to the porosity or absorption of the timber subjected to the process.

Oak and fir timber absorb nearly alike, but the domestic woods, beech, poplar, elm, &c., are more porous.

HYDROMETER.



An hydrometer will mark accurately the strength of the solution, water being 0° (*vide* diagram); then, when the hydrometer sinks to 6°, it denotes that the solution contains 1 lb. of sublimate to 15 gallons of water; when it rises to 17°, 1 lb. of sublimate to 5 gallons.

As a general rule, when it stands midway between 5 and 10°, the solution will be the proper strength.

The corrosive sublimate will dissolve best in tepid water.

The period required for saturating timber depends on its thickness: 24 hours are required for each inch in thickness, for boards and small timbers.

The timbers, after saturation, should be placed under a shed or cover from the sun and rain, to dry gradually.

In about 14 days, deals and timber not exceeding 3 inches in thickness will be perfectly dry and seasoned, and fit for use. Large timbers will require a proportionate time according to their thickness.

The solution may be used ad infinitum, as its strength is not diminished; but it will be advisable to ascertain occasionally by the hydrometer that it contains the required proportions of corrosive sublimate and water.

Professor Faraday and the late Dr. Birkbeck have, with many other scientific men, testified in the strongest manner to the efficacy of this solution. The former says, with respect to the penetration of the solution by steeping, *without* pressure, it may be tested by the application of a drop of hydro-sulphuret of ammonia, which will turn black on meeting with the mercury.

In the cube of elm, the corrosive sublimate may be traced by the above test to the depth of from $\frac{1}{8}$ to $\frac{1}{4}$ of an inch; by the test of voltaic action, from $\frac{3}{4}$ to 1 inch.

In the cube of oak, with the same test, it was found at $\frac{1}{4}$ of an inch, but irregular, and apparently followed the fissures of the wood; by voltaic action, not quite so far as in the elm.

In the cube of fir, the penetration was the least by the common test, $\frac{1}{8}$ to $\frac{1}{6}$ of an

* By Lieut.-Colonel Alderson, R. E.
† See the first volume of 'Professional Papers,' Article XIX.

inch; by voltaic action ½ of an inch, the turpentine in the wood probably being the obstruction to penetration.

From this testimony it is evident that when pressure is *not* used, the timber should be worked up into the form required for use prior to immersion.

The Patentees or Company, who have also the means of saturating with hydraulic pressure at their establishment, similar to that at Portsmouth Dockyard, under Sir William Burnett's process, grant licenses at the rate of 5*s.* per cubic foot internal dimensions of the tank, and sell corrosive sublimate at 4*s.* per ℔.

1½ ℔. is sufficient to saturate a load of timber of 50 cubic feet, at the rate of 1 ℔. of sublimate to 15 gallons of water.

The process has been for several years extensively used for sleepers on railroads.

Within the last year, several of the sleepers on the South Western Railway, which had been subjected to this process, have been taken up, owing to their being decayed, particularly in the chalk districts. It is, however, stated by the Engineer that they were steeped by themselves in a hasty manner, and that he does not consider it conclusive against the process: that he has never seen any wood decayed that had been steeped by the Patentees.

It is also said that neither Kyan's, Burnett's, nor Payne's process, can resist the combined effects of moisture and great heat, say 80° Fahr.

BURNETTIZING.

Burnettizing is the process by means of which timber, felt, canvass, cordage, cottons, and woollens, may be preserved from dry-rot, mildew, moth, and premature decay. It takes its name from its inventor, Sir William Burnett, M.D., K.C.B., F.R.S., of the Navy, who took out a patent for it in 1837.

It consists in immersing the various substances above enumerated in a solution of chloride of zinc and water in a wooden tank,* in the proportion of 1 ℔. of chloride of zinc to 4 gallons of water for wood, and 1 ℔. of the chloride to 5 gallons of water for the remainder of the articles, with the exception of *felt*, which requires 1 ℔. of the chloride to *two* gallons of water.

Three-inch deals require to remain in the tank or cistern *six days*, and all other woods in the same proportion, or two days per inch. They are then taken out and put under a shed, on their ends, to dry, and require for this purpose from fourteen days to three months, according to the thickness of the wood, when they are fit for use.

The timber should be reduced to the scantling required for use before it is subjected to this process.

Canvass, yarn for cordage, cottons, and woollens, require to be suspended in the solution for forty-eight hours.

The process, however, with respect to timber, is much more expeditiously and effectively done by hydraulic pressure in Her Majesty's Dockyard at Portsmouth, where large quantities of timber, &c., are prepared for the use of the Royal Navy at the various dockyards in England, particularly for ships' magazines.

There is a large wrought iron tank, 52 feet in length and 6 feet in diameter, with a door 2 feet 6 inches × 2 feet at each end for loading.

Timber of all sizes and descriptions is put into this cylinder, which contains about *twenty* loads. As soon as it is filled, and the doors well secured both against external and internal pressure, the air is exhausted in the cylinder, and also in the timber, by means of an air-pump worked by a small rotatory engine of ten-horse

* See the first volume of 'Professional Papers,' Article XIX. on Anti-Dry-rot.

power, on the Earl of Dundonald's principle, until the barometer stands at 27°: the valve leading to the air-pump is then shut, and the cock of a pipe leading from the tank, filled with the solution, to the cylinder, is turned: the solution rushes into the cylinder to fill up the partial vacuum, and about half fills it, when the cock is turned, and the air-pump again set to work until the barometer stands at 27½°, when the same process is repeated, and the cylinder nearly filled with the solution.

A pressure of 150 ℔s. per square inch is then obtained by means of a Bramah forcing-pump, connected with an iron copper or reservoir, filled with the solution, and communicating with the cylinder by means of a pipe. This is worked by hand until a valve placed on the top of the cylinder, and loaded to the required gauge, begins to lift.

The timber is then left in the cylinder, subject to this pressure, for *eight hours*, which is considered sufficient for the largest logs, even in a rough state. The solution being then drawn off into the tank, and the timber taken out of the cylinder, it is re-loaded, and the process repeated: the same solution is used for two months, when fresh is prepared.

The same process for drying the timber thus saturated is adopted, as before stated. Canvass, felt, and yarn, &c., are not subjected to pressure.

The felt* is used as a lining to the magazines of men-of-war, between two thicknesses of wood; also to cover over the steam boilers of steam ships: it is said to be rendered much less liable to combustion by the process.

The Patentees grant licenses for the whole term of the patent, at the rate of 3*s.* per cubic foot, according to the internal area of the tank; or a rental of 1*s.* per cubic foot per annum, agreeably to the same measurement, for the same term. In either case they undertake to supply the chloride at 1*s.* per ℔.; 1 ℔. being sufficient for 4 gallons of water.

When the license is not desired for the erection of the tanks, the chloride is charged at 1*s.* 6*d.* per ℔.

The testimonials in favor of the efficacy of this preparation are very numerous and of the highest kind, particularly from Officers of the Navy and persons connected with that department.

It is also stated that in tropical climates, more especially in Africa, the saturated canvass† has stood the climate, when the unprepared, under similar circumstances, has rapidly decayed.

Both Burnettizing and Kyanizing offer great advantages to the Engineer:

1st. Wood of every kind is rendered more durable, and is rapidly seasoned.

2ndly. It brings into general use larch, poplar, and a variety of other indigenous woods, as well as American pine, &c., which, without the process, from being liable to rapid decay, and being much inferior to Baltic timber, are seldom used in public buildings.

To the Military Engineer, these inventions offer still greater advantages. He is frequently called on, in distant colonies, to construct block-houses, stockades, bridges, and barracks, where the only material to be had in abundance is the tree standing in the forest: to him a few pounds of either ingredient would be invaluable, by enabling him to season and render durable the timber a few days after it was cut

* An Indian-rubber felt, composed of *caoutchouc* and cork, is now made, and the inventor is trying to introduce it into the Navy.—R. S. A.

† Some experiments were tried in Dublin in 1845, 6, and 7, under the direction of the Commanding Royal Engineer, on *sand-bags* which were Kyanized and Burnettized, by way of judging if the sand-bags could be used a second time, but without success: they were found in all cases in a state of decay.—*Editors.*

down; and thus provide him with the ready means of rendering a distant post tenable in a short time by a small body of men, with the satisfaction of knowing that the work thus hastily erected was of a permanent nature.—R. S. A.

L.

LABORATORY—The department of the Ordnance intrusted with the manufacture of gunpowder and other substances for military purposes, such as blank and ball cartridges for muskets and carbines, cartridges for every description of ordnance, percussion caps, rockets, and every kind of *laboratory stores*.

The laboratory department is likewise intrusted with the conservation, packing, re-storing and supply of all gunpowder to the several Naval and Military departments, and is managed by a

Director,
Fire Master,
and several Assistant Fire Masters,

who are generally Officers of the Royal Artillery.

Officers of Artillery, as well as the non-commissioned officers and gunners, are instructed in the *laboratory* duties, and carefully taught the manipulation and manufacture of laboratory stores: for the nature, composition, and manufacture of these, see the Article 'Pyrotechnics—Military.'—G. G. L.

LEVELLING*—The art by which we determine the relative height of any number of points.

The height of a point is the vertical distance to which it is elevated or depressed, as compared with the *true general surface of the earth.*

The earth is in form a spheroid. On land we can nowhere trace its true geometric surface; but the sea, when at rest, presents everywhere a very near approximation to it, and hence the *level of the sea* has been assumed as the standard to which all heights are referred.

The absolute height, then, of any point is its vertical distance from the *level of the sea:* the relative height of two or more points, commonly called their *difference of level,* is the difference of those vertical distances.

A *true level* is any surface or line which is parallel to the true geometric surface of the earth; every true level must, therefore, necessarily present a curve everywhere perpendicular to the direction of gravity. It is a beautiful property of fluids that in every situation, when at rest, their surface will present a *true level.*

All points situated within the same true level are evidently at the same height.

One point is said to be higher or lower than another, according as a true level traced through it passes above or below that point; and the vertical distance at which it so passes, is the measure of their relative height.

In theory, levelling is extremely simple. It consists in tracing through space a series of level surfaces, and finding their intersections with vertical lines passing through the points whose *relative height* we wish to ascertain.

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* By Captain Laffan, Royal Engineers.

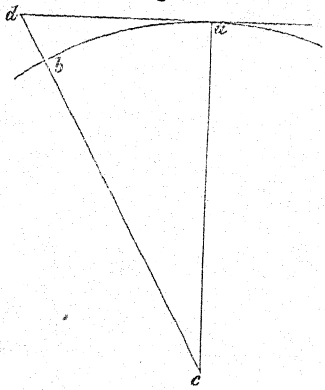
Thus, in order to determine the relative height of two points, we establish at some convenient spot in their neighbourhood a truly level surface, and with the eye, assisted, when necessary, by optical instruments, we endeavour to trace the continuation of that surface till it intersects vertical lines passing through the two points. The vertical distances from each point to its corresponding intersection will give the difference of level between that point and the observer's eye; and the difference or the sum of those vertical distances, according as the points are on the same or on different sides of the level surface, will give the difference of level sought.

In practice, however, the simplicity of the theory is disturbed by two sources of error, called the errors of *curvature* and *refraction*.

The first arises from the spheroidal form of the earth, in consequence of which all true levels must necessarily be curves; whereas we can only trace horizontal lines or planes tangent to those curves at the points whereon we stand. These we call the 'apparent,' to distinguish them from the 'true' levels.

In thus substituting the apparent for the true levels, we evidently give rise to an error in the observation, the effect of which is to *depress* the apparent place of any distant point. This effect increases the further our observations extend: within short distances of 200 or 300 yards it is so small that except in extremely accurate levelling it may be overlooked, but for greater distances it is necessary to apply a correction. (See fig. 1.)

Fig. 1.



If we suppose $a\,b$ in the annexed figure to represent a portion of the earth's surface, a the point where the observer stands, and b the point observed, c the centre of the earth, and $a\,d$ a horizontal line or 'apparent level;' then $b\,d$ is the error of curvature due to the distance $a\,b$, and it is evidently the difference between the radius and secant of the arc $a\,b$. If we call this difference x, the arc or distance D, the tangent or apparent level t, and the radius r, we have the following equation:

$$(r + x)^2 = r^2 + t^2,$$

from which $x\,(2\,r + x) = t^2$; and as the quantity (x) must always be extremely minute when compared with the earth's radius, we may substitute $2\,r$ for $(2r+x)$, and, in the same way, we may substitute D^2 for t^2, when we shall have

$$x \,.\, 2\,r = D^2,$$

$$\text{whence } x = \frac{D^2}{2\,r}.$$

It appears, then, that the error increases as the square of the distance between the observer and the point observed. Assuming the mean diameter of the earth to be 7916 miles, we find the correction for curvature for one mile to be 0·667 of a foot, or 8·004 inches. A formula easily remembered is, that the correction in feet is equal to $\frac{2}{3}$ the square of the distance in miles; or that the correction in inches is equal to $\frac{1}{800}$ the square of the distance in chains.

The second source of error, *terrestrial refraction*, has a contrary effect to that of curvature, inasmuch as it tends to elevate the apparent place of any distant point. It varies in amount according to the state of the atmosphere, but, as a general rule, it may be assumed equal to $\frac{1}{7}$ the error of curvature; and as it acts in a contrary

direction, it must be subtracted from it. The correction, in feet, for the two combined will be $\frac{4}{7}$ the square of the distance in miles.

These corrections are very troublesome, and, whenever it is possible, it is desirable to do away with the necessity for applying them. This can generally be done by choosing, as a point to level from, some spot equidistant from the points we wish to observe. The errors both of curvature and refraction then compensate themselves, for they act equally both ways. In the series of observations, however, required to level a long line, instances will frequently occur in which it is impossible to observe from a point equidistant from the other two; but even in this case the errors may be compensated in the next observation, by making the point of observation equally eccentric the opposite way.

The instruments made use of in levelling operations are founded upon two principles.

1st. Every line or plane perpendicular to the direction of gravity is horizontal or apparently level.

2nd. The surface of every liquid at rest being a true level,—all lines or planes tangent to such surfaces will be apparent levels.

On the first of these is founded the common mason's level and all reflecting levels.

The second is the principle of the simple water level and of the various descriptions of spirit levels now in use.

The common mason's level is too well known to need a description; it will do for rough work and short distances, but should never be used whenever a superior instrument can be procured. In military reconnaissances, however, it might be turned to some account by adding a graduated arc described from the summit as a centre, and numbered on each side from the centre line. On applying it then to any slope, the string would mark on the arc the exact angle of inclination we desire to know. (See figs. 2 and 3.)

Fig. 2.

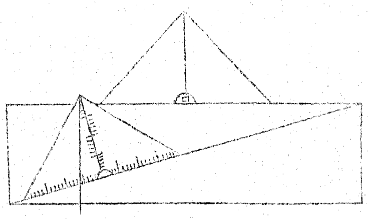
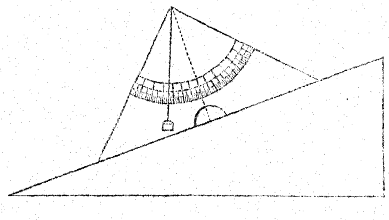
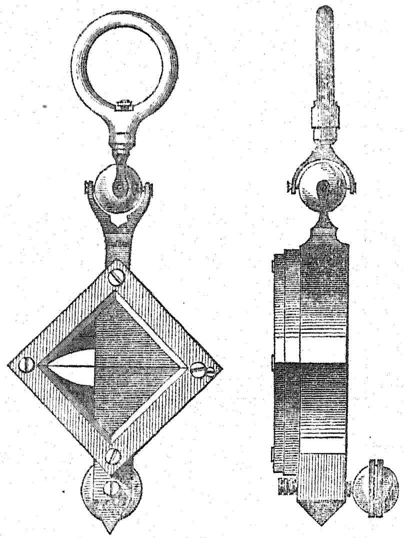


Fig. 3.



The reflecting levels consist of a small piece of looking-glass set in a metal frame, and suspended from a point so adjusted that the plane of the glass shall be always vertical. It is evident that when we see the reflection of our own eye in

Fig. 4.

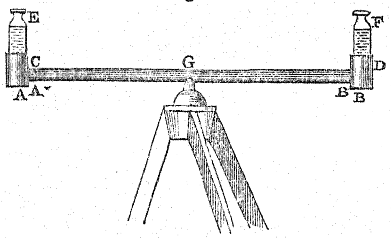


the mirror, the line from the pupil to its reflected image must be perpendicular to the plane of the glass, and therefore to the direction of gravity. By shifting the instrument, therefore, we have the means of tracing any number of horizontal lines. Reflecting levels are beautiful in theory, and very portable, but in practice they are not susceptible of great accuracy. They are very good for a military reconnaissance. (See fig. 4.)

The water level is generally used for filling up the details of more extended observations, and for all operations at short distances where great accuracy is not required. It is a very convenient instrument, easily made, and having the great advantage of never getting out of adjustment.

The water level is peculiarly adapted to the tracing of contour lines, an important branch of military surveying; and as it may prove of service to military men where superior instruments cannot be procured, the following description and sketch are annexed, to enable any one to construct one for himself with no further aid than such common workmen as are to be found in every village. A B is a hollow tube of brass or tin, 3 feet long and ½ an inch in diameter; the ends soldered into other short tubes C and D, of larger diameter, to receive the small bottles E and F, the bottoms of which have been cut off by tying a piece of wet string round them when heated. The bottles are fixed in the tube with putty or white lead. G is a sort of vertical axis, soldered on to the tube, and working in a cylindrical metal socket fixed to any kind of portable stand or frame. When the instrument is required for use, the tube is filled with water till it reaches nearly to the necks of the bottles, and these are then corked for the convenience of carriage. On setting the instrument up, care should be taken to bring the tube as nearly as possible level by the eye, and the corks being then withdrawn, the water will occupy precisely the same level in both bottles, thus giving us the means of tracing a horizontal line in whatever direction we may turn the tube. The bottles should be an inch in diameter, and of rather thin white glass. The water must be slightly coloured (cold tea answers very well).

Fig. 5.



The spirit levels in general use are the ordinary Y level, so called from the nature of its supports, and Troughton's improved level. These instruments are so well known that it is unnecessary to describe them; but the following directions for their adjustment may be found useful.

In the Y level there are three points to be attended to:

1st. To see that the intersection of the cross wires is exactly in the centre of the telescope. This is called the adjustment for the line of collimation.

2nd. To see that the level is exactly parallel to the axis of the telescope.

3rd. To see that the axis of the telescope, or line of collimation, is perpendicular to the vertical axis upon which it turns.

The first of these is tested by making the intersection coincide with some well-defined distant point, and then turning the telescope round into the Y's. If the adjustment be correct, the coincidence will remain perfect during the whole revolution; but if in error, the intersection will be seen to describe a small circle on the distant object. In the latter case the wires must be moved by means of the small screws of the diaphragm till their intersection occupies the centre of the observed circle. If this be correctly estimated, the telescope may be turned round again without any eccentricity being observed: generally speaking, however, this adjustment will require repeated trials.

The second adjustment is tested by bringing the telescope over two of the plate screws, and moving the latter till the bubble is in the centre. The telescope is then to be reversed in the Y's, and if the bubble still occupy the centre, the adjustment is correct. Should it, however, incline to one side, it must be brought half-way back by the capstan-headed screw under the end of the level, and the remaining half by the plate screws. If this be correctly done, the bubble will remain in the centre in both positions. Owing, however, to the difficulty of estimating the half-error, this adjustment will generally be found to require many trials.

The third adjustment is also tested by bringing the telescope over two of the plate screws, and the bubble to the centre; but, instead of reversing the telescope in the Y's, the instrument is turned round a half circle on the vertical axis, when the telescope will be again over the same screws the reverse way. If the bubble has moved from the centre, it must be brought half-way back by means of the milled screw under the Y near the eye-piece, and the remaining half by the plate screws. The same operation being repeated with the other pair of plate screws, the adjustment will be complete.

N.B.—No instrument should ever be used till it is ascertained that these adjustments are correct.

In Troughton's* improved level, the spirit level itself is firmly bedded in the telescope; there are therefore only two adjustments:

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* "*The Dumpy Level.*—This modification of the spirit level has but recently been introduced by William Gravatt, Esq., and bids fair to become the favorite instrument among Civil Engineers. In its general figure it does not differ very essentially from Troughton's improved level, but it possesses many decided advantages. The aperture of the object glass is much larger for the same length of telescope; consequently more rays of light are admitted to the eye, producing the advantages of greater distinctness. We lately tried a *fourteen-inch* level, constructed upon Mr. Gravatt's principle, and found that we could distinctly read the levelling staff at twenty chains (a quarter of a mile) distant, which was the utmost we could do with a *twenty-inch* level upon the old construction: we have, therefore, the advantage of a more portable instrument, fourteen inches in length, capable of performing the same work as a more cumbersome one of twenty inches. Besides this advantage, the instrument in question is more complete in its details. It possesses a cross level, placed at right angles to the principal level, which affords very great facility in setting up the instrument, and adjusting for observation: it likewise has a reflecting mirror, mounted with a hinge joint, and capable

1st. To make the level perpendicular to the vertical axis.

2nd. To make the line of collimation parallel to the level.

The first is effected in the same way as in the Y level, substituting for the milled screw under the Y the capstan screws which attach the telescope to the horizontal bar.

The second adjustment is effected by noting the height of the intersection of the cross wires on a staff two or three hundred yards distant, and then making the instrument and staff change places. If the difference of level remain the same, the adjustment is correct; if not, the vane on the staff is to be moved one-half the observed difference, and the intersection made to coincide with it by the diaphragm screws near the eye-piece.

A sheet of water furnishes an easy mode of adjusting the line of collimation. A mark being fixed at some convenient distance, at exactly the same height from the water as the instrument to be adjusted, the cross wires have only to be made to intersect each other at that point.

The telescopes of spirit levels are generally provided with one horizontal and two vertical wires. Some have also a finely divided micrometer scale, which is a very useful addition, inasmuch as it enables the observer to read off any small portion of the staff that may be intercepted between the horizontal wire and the nearest upper or lower division. It may also be used where minute accuracy is not required, to fix approximately the staves at equal distances from the instrument, or even to estimate the actual distance of any point.

In order to read the staff by the micrometer scale, it is necessary to note the run of the latter for each observation, as it will necessarily vary with the distance.

In order to fix the staves approximately at equal distances from the instrument, it suffices to note the value upon the scale of any given unit at the back station, and then cause the second staff to recede till a similar unit subtend the same number of divisions.

If we wish to estimate the actual distance of any point, it is necessary to have a Table prepared from previous observation, shewing the number of divisions of the scale a given height on the staff (say 5 or 10 feet) subtends at 100, 150, 200, and so on to 1000 feet. Intervening distances may be found by taking the nearest number of divisions in the Table, and the distance corresponding to it: these will form the two first terms of an *inverse proportion;* the third being the observed number, and the fourth the distance required.

The levelling staves made use of for ordinary levelling are unprovided with vanes, the divisions, 10ths and 100ths of a foot, being so distinctly marked that the observer is enabled to read them off himself. The figures are generally inverted, to suit the inverting telescopes now in use. The staff rests upon an iron slide, within which it can be turned upon a pivot without being lifted from the ground.

Where minute accuracy is required, the staff is never turned; it is provided with vanes facing in opposite directions, and, whenever it is possible to avoid it, the vane recording one observation is never disturbed till the next is obtained.

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of being placed on the principal level tube, and adjusted, to shew the observer if the instrument shifts from its horizontality whilst he is noting the observation: it also possesses other important though minor additions, all of which, in fact, could be applied by the maker to the other kind of instruments, if ordered.

"From the large aperture and short focal length of the telescope, the instrument has altogether a dumpy appearance, and hence it is generally known by the cognomen of 'Gravatt's Dumpy Level:' usually of nine or fourteen inches. We have seen some beautiful specimens of this kind of levelling instrument constructed for I. K. Brunel, Esq."—*Simms on the Practice of Levelling.*

The vanes are generally of metal: they move on the staff by means of a sliding clasp. This again is connected by an adjusting screw with a spring clasp, somewhat lower down; and the latter can be firmly attached to the staff, when necessary, by means of pushing screws. The adjusting screw is finely cut, so as to admit of a delicate adjustment. When the vane is so high on the staff that the arm cannot reach to manipulate it, a rod is made use of, having a universal joint fitting the head of the screw. A triangular space is cut out from each side of the vane, and the axes are made to coincide with the zero of the vernier which divides the staff. Small mirrors are fitted to the back of these openings, moving upon hinges, so as to reflect the light towards the telescope at different angles of incidence. In observing, the horizontal wire will be seen very sharp and distinct upon the faces of these mirrors: it is made to bisect the triangles, and thereby to coincide with the zero of the vernier; the latter is divided to ·001 of a foot, and the reading can be carried to a fourth place of decimals by the eye. (See figs. 6, 7, and 8.)

Fig. 6.—Back View.

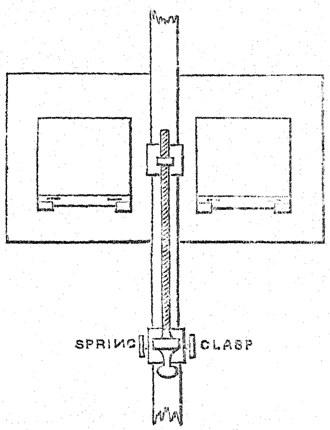


Fig. 7.—Front View.

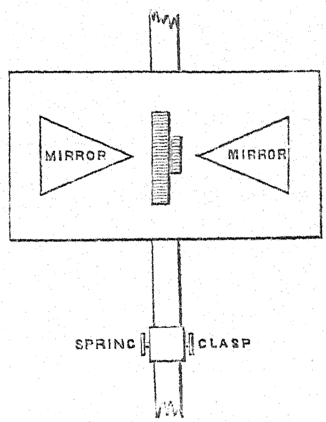
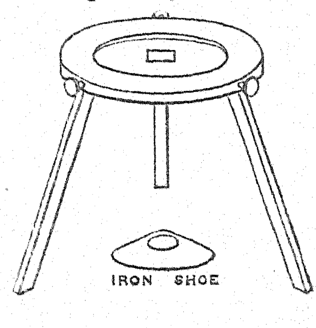


Fig. 8.—Tripod Stand.



The staves are supported by tripod stands, having on the top a strong brass plate, to which a horizontal motion can be given by means of adjusting screws. The staff is passed through an opening in this, and rests below upon a massive iron shoe, in which an orifice has been made to receive it. The vertical position is then insured by means of the adjusting screws.

A strong wind generally causes so much vibration and unsteadiness in the staves that it is difficult to obtain a satisfactory result. In this case a strong canvass screen, placed to windward, will be found to diminish the vibration very materially.

METHOD OF OBSERVING.

The method of observing adopted for ordinary levelling is to divide the line to be levelled into convenient lengths, seldom placing the staves more than 400 or 500 feet apart. The instrument is placed as nearly as possible equidistant from the staves, by which means the errors of curvature and refraction are got rid of, and even a slight error in the collimation of the instrument cannot materially affect the result. The heights marked upon the staves by the horizontal wire are then read off by the observer himself, and entered in a field-book, and the difference of those heights gives the difference of level between the first two points. The staff at the back station is then sent forwards, the instrument again set up at some point equidistant from the staves, and another observation taken which fixes the comparative level of another point. These operations are repeated as many times as may be necessary to complete the whole line; the forward station of one observation necessarily becoming the back station of the next.

The observations are generally entered in the form of a Table: this may be drawn up in various ways. The following is given as a simple form:

No. of Observation.	Distance between the Staves.	Back Station.	Forward Station.	Rise.	Fall.	Total Rise.	Total Fall.	Remarks.
1	400	5·72	11·35	—	5·63	—	5·63	
2	350	4·31	6·54	—	2·23	—	7·86	
3	480	2·17	9·89	7·72	—	—	0·14	
4	300	3·35	8·60	5·25	—	5·11	—	

In the first column is entered the number of the observation; in the second, the distances between the staves. The third and fourth shew the readings of the instrument, and the differences of those readings are entered in the fifth or sixth column, according as the result shews a rise or fall between the two points. In the seventh and eighth columns are carried out the total rise or fall of each point from the first station; and the ninth column, headed "*Remarks*," contains references to bench-marks, cross sections, or any other information that may be subsequently required.

Where great accuracy is required, a level of larger dimensions than ordinary is employed: a small riding level is adjusted to the horizontal wire, and besides insuring the correct position of the latter, is very useful in setting up the instrument approximately level. The micrometer scale is divided to 200ths of an inch. The staves made use of are those with metal vanes and mirrors before described, and canvass screens are provided to protect them from the wind.

In observing, the instrument should always be placed by measurement equidistant from the two staves. The distance of each should rarely exceed 200 or 300 feet, and in marshy or soft ground it should be diminished to 150 feet. When the instrument has been adjusted and the bisection of the sight vane made, the assistant at the staff reads off the vernier and inserts the reading in a rough field-book. The vane is then shifted, and the instrument thrown out of true level. The latter is again adjusted, a second observation made, and the assistant records it as before. If the two readings do not differ more than $\frac{1}{500}$ of a foot, he makes a signal to the observer, who proceeds to the staff, and enters a third independent reading of the vernier in his own rough field-book. This is compared with those of the assistant, and an entry made in the fair field-book of the mean of the three. If, however, the two first observa-

tions differ more than $\frac{1}{500}$ of a foot, the observations are repeated till a fair series is obtained; after which an independent reading is entered by the observer as before.

If the line to be levelled be a long one, it should be divided into intervals, the length of which must vary with the facility with which proper bench-marks can be found. These latter should be very permanently recorded; the best consist of copper bolts let into the corners of stone buildings, towers of churches, &c., and run with lead. Their position should be accurately defined in the field-book.

The following is the form of field-book used:

Date.	Hour.	Barometer.	Attached Thermometer.	Hygrometer.	Attached Thermometer.	No. of Observation.	Bearing of the Back Station.	Distance of Back Station.	Bearing of Forward Station.	Distance of Forward Station.	Number of Divisions of Micrometer Scale for 1 foot of Staff.	Back Reading.	Front Reading.	Rise.	Fall.	Total Rise.	Total Fall.	Remarks.

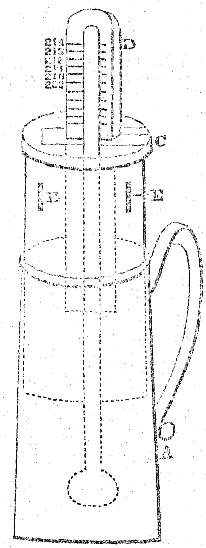
ON THE USE OF COMMON THERMOMETERS TO DETERMINE HEIGHTS.*

Having been recently applied to by two gentlemen about to travel—the one in Africa and the other in Asia Minor—for a description of the thermometers and apparatus used by myself for some years in India for determining heights by the boiling temperature of water, I have ventured to believe that a brief account of a process which I found to produce results sufficiently near to the truth for most practical purposes, may not be unacceptable to some members of the Society, particularly as I carried on my barometrical observations contemporaneously, and thereby obtained data for fixing the value of certain points on the thermometric scale. To determine heights accurately, good barometers are necessary, which have been carefully compared with a standard barometer: the observations must be taken simultaneously at the upper and lower stations, and the temperature of the mercury and the air, and the hygrometric state of the latter, must be noted. Heights so determined, when tested again in the same or succeeding years, I have rarely found to vary more than 10 or 20 feet in 4000 or 5000. When barometers are used which have not been previously compared with a standard, when the observations are not simultaneous, and when the pressure and temperature at the level of the sea are *assumed*, the results may by accident be near to the truth, but they will usually be from 100 to 300 feet wrong,—at least such is the result of my experience within the Tropics. But good barometers are very costly; they are troublesome to carry, are particularly exposed to accident on a journey, and get out of order by the escape of the mercury, which being frequently unobserved, the barometer continues to be used as if it were

* By Lieut.-Col. W. H. Sykes, F.R.S., [extracted from the eighth volume of the 'London Geographical Journal,' by permission of the Author.]

correct. The late Archdeacon Wollaston, aware of these facts, invented the thermometric barometer to supply the place of the ordinary barometer. This instrument is very sensible, but it is very fragile from the great weight of the bulb compared with the slenderness of the stem; moreover, there are some complex accompaniments, and the instrument is also expensive: in short, I found it not fit for *rough work* out-of-doors, having had three destroyed at the outset of my labours; and the same opinion is expressed by Mr. James Prinsep, of Calcutta, who is well known for the practical application of his scientific knowledge. I had then recourse to common thermometers, and, with certain precautions in their use, found them answer my purpose sufficiently well. A tin shaving-pot was my boiler; dry sticks and pure water were usually to be had, and by the time my barometers were settled, I was ready to take the boiling temperature. The following is a sketch of the apparatus.

Fig. 9.



A, A common tin pot, 9 inches high by 2 in diameter.
B, A sliding tube of tin moving up and down in the pot; the head of the tube is closed, but has a slit in it, C, to admit of the thermometer passing through a collar of cork which shuts up the slit where the thermometer is placed.
D, Thermometer, with so much of the scale left only as may be desirable.
E, Holes for the escape of steam.

It will be seen that the chief part of the scale usually attached to the thermometer is removed, only so much of it being left as may be desirable: I however permitted the brass scale of one of my thermometers to remain, and I did not discover that it was the cause of error. Previously to taking the thermometers inland, it is necessary to ascertain their boiling points at the level of the sea; for in many instances the scales are so carelessly applied, that a thermometer may indicate a boiling temperature of 213°, 214°, or 215° at the level of the sea; one of mine stood at 214·2 when water boiled. Nevertheless, by making a deduction of 2° 2′ in all observations, the indications rarely differed five-hundreths of a degree from the other thermometer, of which the boiling point was 212°: the temperature of the air and the height of the barometer at the time the *verification* of the thermometers is made must be noted. The following is the manner in which my observations were taken:—from 4 to 5 inches of *pure* water were put into the tin pot; the thermometer was fitted into the aperture in the lid of the sliding tube by means of a collar of cork; the tin tube was then pushed up or down to admit of the bulb of the thermometer, being about *two inches*, above the bottom of the pot. Violent ebullition was continued for 10 minutes or a quarter of an hour, and the height of the mercury was repeatedly ascertained during that time, and the temperature of the air was noticed. Similar operations were repeated with a *second* thermometer, for it is never safe to rely upon *one* instrument. Having obtained the boiling points, it remains to determine the value of the indication of diminished pressure when the observations are taken above the level of the sea. The elastic tension of steam at different points on the thermometric scale has been determined by experiment, but not at regular intervals on the scale, nor with similar results, by different persons: Tables, therefore, computed from the formulæ of the various experimenters, do not accord; but, in three Tables which I have in my possession, the heights computed by them, when compared with heights determined by corresponding barometrical observations with previously compared barometers,

(the only satisfactory way to ascertain heights not taken trigonometrically,) approximate sufficiently near for all practical purposes where great accuracy is not desired. These Tables, however, differ slightly from each other.

The Table which first came into my hands appeared anonymously in the 'Madras Gazette' for 1824. In 1826, an able friend, Lieut. Robinson, of the Indian Navy, who entered warmly into my views to determine heights by common thermometers, thought he could improve upon the Table I was using, and accordingly made a new computation: the third Table came under my notice much more recently than the two former. It is computed by Mr. James Prinsep, of Calcutta, Secretary of the Asiatic Society of Bengal, a gentleman distinguished for his scientific research. He published it in the Journal of the Society. To admit of a just estimate being formed of the value of these Tables,—of the value of corresponding barometrical observations, made with due precautions, although with different coadjutors and different instruments,—of the value of barometrical observations, with an assumed pressure and temperature, at the level of the sea,—of the value of thermometrical compared with barometrical observations,—out of many hundred heights determined in various ways, I have taken many at random, (the number it appears is eighty-eight,) and I have put them into juxtaposition in a tabular form. In thermometric heights, the elements at the level of the sea were a boiling temperature of 212° Fahr. and a mean temperature of the air of 82°. The *assumed* pressure in heights determined barometrically, without corresponding observations, was 30 inches; mean temperature 82°. In looking over the tabulated results, I was a good deal surprised to find that in no instance, by whatever method determined, do the barometric differences in height exceed 127 feet, and this only by comparing the highest indications with an assumed pressure with the lowest indications of corresponding observations. It will be seen that the various Tables for determining heights thermometrically, with certain exceptions, do not differ very *materially* in their results from each other, nor from corresponding barometric observations; the formulæ on which they are founded may therefore be considered, on the whole, sufficiently accurate for the present state of our knowledge.

Lieut. Robinson's and Mr. Prinsep's Tables give close approximations to each other in their results, but they are as much below the corresponding barometric observations, which I consider the true heights, as the results by the Madras Table are above the true heights. Some of them curiously coincide within a foot or two of the heights determined by corresponding barometrical observations, but this coincidence must be the result of mere accident. Taking the mean of all the thermometric observations at a station calculated by the three Tables, and the mean of all the corresponding barometric observations at the same place, the utmost difference is 107 feet in less than 600; and the least difference is 8 feet in about 3000; but as the thermometric heights in which the difference of 107 feet occurs were single observations, made by a gentleman who had newly begun to use his thermometers, they may be looked upon as probably less accurate than subsequent trials would have made them. This is scarcely an unjust inference, as it will be seen that the next greatest difference made by the same gentleman was only 24 feet in 1490. It must be admitted, however, that this amount of error is just as likely to occur in heights of 100 feet as in those of 10,000. My thermometers were not graduated to less than half-degrees, and long practice enabled me to determine the height of the mercury in the stem to one-twentieth of a degree; but I would recommend thermometers being used in which the degrees are graduated to fifths or tenths of a degree. On the whole, I think the results of six years' experience justify me in saying that common thermometers may be satisfactorily used to supply the place

of barometers in measuring heights where great accuracy is not required; and it will be recollected that what is usually looked upon as a difficult and troublesome operation with barometers, will be attainable by any person who carries with him a couple of thermometers,* the requisite tin pot, and the Tables, and who is master of the simplest rules of arithmetic.

Of the three Tables in my possession, I have chosen Mr. Prinsep's from their perspicuity and the facilities they offer for the conversion of boiling temperatures into heights with very little trouble; but a glance over the figures in my Tables of Altitudes will show that the Tables are susceptible of considerable improvement, for with two exceptions, all the heights deduced from Mr. Prinsep's and Lieut. Robinson's are much below those determined by simultaneous observations with good barometers; and I join with Mr. Prinsep in expressing a hope that every traveller boiling his thermometers will at the same time, if he possess a barometer, make a record of its indications, and thus render essential service to physics by fixing so many points on the scale of the elastic tension of steam at different temperatures.

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* SEVENTEENTH MEETING OF THE BRITISH ASSOCIATION.

"*Barometrical Levelling in the Madras Presidency by General Cullen, with Observations by Colonel Sykes.*

"Colonel Sykes exhibited and explained two maps constructed by Gen. Cullen, of the Madras Artillery, comprising five sections of country, shewing the relative levels by barometrical observation at distances ranging from 10 to 20 miles: one section of about 1170 miles—another being a road distance of 543 miles. The second map contained three sections,—one of 265 miles, another of 280 miles, and a third from Madras to Arcot road, a distance of 293 miles. A third map gave barometrical sections from Madras to Bellary, on a line about W. N. W. 244 miles; and from Bellary to Jelalamacul, on a line about W. and S. 156 miles. This map, without pretending to be a complete geological section, shewed the prevailing rocks on the route. Associated with the sections were notices of the climate and mortality at most of the stations, comprising the maxima, minima, and extreme pressure of the barometer for some years,—the maxima, minima, and mean indications of the thermometer,—the falls of rain,—the nature of the monsoons,—and the sickness and per centage mortality of the European and Native troops. The whole of these laborious results indicated no ordinary industry and judgment. *Colonel Sykes's* object in exhibiting the sections was to call the attention of Railway Engineers to the use of the barometer as the precursor of the theodolite, in determining the general levels of a country with a view to the selection of lines. He suggested also that geologists might use the barometer to fix the heights above the sea of the strata described. He stated that in the Tropics the moderate oscillations of the barometer admitted of levels being determined with some accuracy even when the instrument was used independently; but that when the instrument used had been previously compared with the standard barometer, and that contemporaneous observations were made, he could testify, from his own experience, that a height so determined might not differ ten feet, when re-tested and re-observed after a lapse of years."—Athenæum, July 17, 1847.

TABLE OF ALTITUDES.

Year.	Date.	Names of Places.	ALTITUDES DEDUCED FROM 1	2	3	4	5	6	7	8	9	10	11	12	13	1
			Jones's Bar. No. 2, with assumed pressure of 30° in., and mean temp. 82° at the level of the sea.	Cary's Barometer, No. 2, ditto ditto.	Corresponding observations with Capt. Jervis's Gilbert's Bar. and Cary's No. 2.	Corresponding observations with Dr. Walker's Gilbert's Bar. and Cary's No. 2.	Corresponding observations with Capt. Jopp's and Cary's Bar. No. 2.	Corresponding observations with Cary's Bars. Nos. 1 and 2.	Corresponding observations with Cary's Bar. No. 1, and Jones's No. 2.	Heights by boiling temperatures, Therm. 1 by the Madras Tables.	Heights by boiling temperatures, Therm. 2 by the Madras Tables.	Heights by boiling temp. by Lieutenant Robinson's Tables, Indian Navy.	Heights by boiling temperatures, by Tables of James Prinsep, Esq., Calcutta.	Difference between the means of *all* the boiling temps. and barometric corresponding observations.	Mean of corresponding observations by Barometers.	Mean of all the boiling
1827	23 May ..	Highest point, Hill Fort of Púrundhur	4588	4599	....	....	....	*4471	4528	4536	4553	4415	4427	−16	4499	44
1827	10 May ..	Singhur Hill Fort	4199	4180	....	....	....	*4211	4170	4341	4220	3927	3928	−86	4190	41
1828	15 May ..	Temple at Bíma Shunkur	....	....	....	....	*3090	....	....	3037	3037	2992	2991	−71	3090	301
1825 1827	6 March 11 May..	Karleh, Cave Temple	2493	2652	....	....	....	*2530	....	2693 2526	2646 2526	2468	2478	+27	2530	25
1827	23 May ..	Highest point of Púrundhur above Púna....	2697	2681	....	....	....	*2648	*2650	2661	....	2539	2566	−61	2649	25
1828	9 Feb... 3 April.	Pait on the Yail River....	....	....	*2478 *2493	....	*2470	....	....	2494	2494	2480	2484	+8	2480	248
1828 1829	....	Temple in the Hill Fort of Huríchundurghur..	3972	3931	3845	*3922	†3871	*3887	3935	3840 3887	3869 3887	3824	3788	−46	3892	384
1829	11 to 17 Dec....	Source of Kristna River at Mahabuleshwur ..	....	....	....	*4496 *4503	....	....	....	†4498	†4556	†4422	†4425	−24	4499	447
1828	27 April ..	Pokrí	....	....	....	....	*3197	....	....	3194	3194	3185	3141	−19	3197	317
1828	6 April ..	Kullumb, on Goreh River	....	....	2043 2027	....	*1995	....	....	1971	2000	1988	1986	−36	2022	198
1825 1826 1827 1828 1829	....	Púna, Hay Cottage	....	....	1810 1820	*1810	*1837	*1823	....	Means 1883	1897	1876	1861	+59	1820	187
1828	16 Feb. ..	Downde, on the Bíma River	....	....	....	....	1623	....	....	1591	1591	1567	1575	−41	1623	1582
1828	29 Oct. ..	Sasswur, above Púna	....	....	....	592	....	....	....	†514	†456	....	....	−107	592	485

* The heights most relied on.

† Boiling temperatures determined by Dr. Walker.

TABLE I.

To find the Barometric Pressure and Elevation corresponding to any observed Temperature of Boiling Water between 214° and 180°.

Boiling Point of Water.	Barometer modified from Tredgold's Formula.	Logarithmic Differences or Fathoms.	Total Altitude from 30·00 in. or the Level of the Sea.	Value of each Degree in Feet of Altitude.	Proportional Part for One-tenth of a Degree.
°			Feet.	Feet.	Feet.
214	31·19		−1013		
213	30·59	00·84·3	507	−505	··
212	30·00	84·5	0	−507	··
211	29·42	84·9	+509	+509	··
210	28·85	85·2	1021	511	51
209	28·29	85·5	1534	513	··
208	27·73	85·8	2049	515	··
207	27·18	86·2	2566	517	··
206	26·64	86·6	3085	519	52
205	26·11	87·1	3607	522	··
204	25·59	87·5	4131	524	··
203	25·08	87·8	4657	526	··
202	24·58	88·1	5185	528	··
201	24·08	88·5	5716	531	53
200	23·59	88·9	6250	533	··
199	23·11	89·3	6786	536	··
198	22·64	89·7	7324	538	··
197	22·17	90·1	7864	541	54
196	21·71	90·5	8407	543	··
195	21·26	91·0	8953	546	··
194	20·82	91·4	9502	548	··
193	20·39	91·8	10053	551	55
192	19·96	92·2	10606	553	··
191	19·54	92·6	11161	556	··
190	19·13	93·0	11719	558	··
189	18·72	93·4	12280	560	56
188	18·32	93·8	12843	563	··
187	17·93	94·2	13408	565	··
186	17·54	94·8	13977	569	57
185	17·16	95·3	14548	572	··
184	16·79	95·9	15124	575	58
183	16·42	96·4	15702	578	··
182	16·06	96·9	16284	581	··
181	15·70	97·4	16868	584	··
180	15·35	97·9	17455	587	·· 59

The Fourth Column gives the Heights in Feet.

TABLE II.

Table of Multipliers to correct the Approximate Height for the Temperature of the Air.

Temperature of the Air.	Multiplier.	Temperature of the Air.	Multiplier.	Temperature of the Air.	Multiplier.
32°	1·000	52°	1·042	72°	1·083
33	1·002	53	1·044	73	1·085
34	1·004	54	1·046	74	1·087
35	1·006	55	1·048	75	1·089
36	1·008	56	1·050	76	1·091
37	1·010	57	1·052	77	1·094
38	1·012	58	1·054	78	1·096
39	1·015	59	1·056	79	1·098
40	1·017	60	1·058	80	1·100
41	1·019	61	1·060	81	1·102
42	1·021	62	1·062	82	1·104
43	1·023	63	1·064	83	1·106
44	1·025	64	1·066	84	1·108
45	1·027	65	1·069	85	1·110
46	1·029	66	1·071	86	1·112
47	1·031	67	1·073	87	1·114
48	1·033	68	1·075	88	1·116
49	1·035	69	1·077	89	1·118
50	1·037	70	1·079	90	1·121
51	1·039	71	1·081	91	1·123

Enter with the mean temperature of the stratum of air traversed, and multiply the approximate height by the number opposite, for the true altitude.

When the thermometer has been boiled at the foot and at the summit of a mountain, nothing more is necessary than to deduct the number in the column of feet opposite the boiling point below from the same of the boiling point above: this gives an approximate height, to be multiplied by the number opposite the *mean* temperature of the air in Table II., for the correct altitude.

	°		feet.
Boiling point at summit of Hill Fort of Púrundhur, near Púna	204·2	=	4027
Boiling point at Hay Cottage, Púna	208·7	=	1690
	Approximate height		2337
Temperature of the air above . . . . 75°			
Ditto ditto below 83			
Mean 79 =	Multiplier		1·098
	Correct altitude		2·566 feet.

When the boiling point at the upper station alone is observed, and for the lower the level of the sea, or the register of a distinct barometer is taken, then the barometric reading had better be converted into feet, by the usual method of subtracting its logarithm from 1·47712 (log. of 30 inches) and multiplying by ·0006, as the differences in the column of '*barometer*' vary more rapidly than those in the '*feet*' column.

Example.—Boiling point at upper station . . . . $185° = 14548$

Barometer at Calcutta (at 32°) 29 in. 75°

Logar. diff. $= 1{\cdot}47712 - 1{\cdot}47349 = 00363 \times 0006 =$ 218

Approximate height 14330

Temperature, upper station, 76° } 80 = multiplier . 1·100
Ditto lower, 84° }

Correct altitude 15763

Assuming 30·00 inches as the average height of the barometer at the level of the sea (which is however too much), the altitude of the upper station is at once obtained by inspection of Table I., correcting for temperature of the stratum of air traversed by Table II.

MEMORANDA ON RAILWAY LEVELLING.*

The circumstances which may influence the selection of the route to be followed in the construction of any projected line of railway may be various, but in general, with a due regard to local and geological considerations, it will be mainly determined from the lines of section obtained by levelling and linear measurement.

As a measure preliminary to the selection of trial lines of section, a careful and minute reconnaissance of the country to be traversed is indispensable. Where maps so full in detail and so accurate in representation of feature as the Ordnance maps of England (scale 1 inch to a mile) are procurable, this proceeding is greatly facilitated; and according to the amount of assistance derivable from such a source, so will the tedium of this stage of operations be increased or diminished.

The water courses and mountain ranges, or ridges in more level countries, will necessarily form the grand guide in this inspection. Much assistance may however be derived, especially in a mountainous country, and where the distances between the termini of the proposed railway is considerable, from barometrical measurements,† and may frequently render it unnecessary to make trial of a line which to the eye might appear to be within the limits of comparison, and even possibly in a short line might lead to the determination of the course to be adopted without further trial. When the barometer is thus brought into requisition, in order to obtain the best results, a means of direct comparison should be constantly maintained with the initial point, which will of course be one of the termini of the proposed line. To this end a second barometer should be provided; both should be set up together, and their readings compared; and whilst the first or travelling barometer is carried forward, the second should be left in charge of an assistant to be noted every quarter of an hour: then, at each point the altitude of which is required, the travelling barometer being set up, the time and readings are to be noted; and when the scale of the guide map admits, as the Ordnance map will do, a point being marked on it indicating the station and a number against it, a corresponding number must be entered in the field-book. Where the aid of such a map is not obtainable, a sufficient description of the station must be written, and its bearing and distance, as well as can be ascertained from previous stations, or from known fixed points, also given.

When the distance of the extreme points of the ground reconnoitred are not more than twenty miles apart, and the tract of country is not mountainous, it may be

* By Captain M'Kerlie, R. E.

† See also in this article ('Levelling'), Lieut.-Colonel Sykes's application of the common thermometer to determine heights.

unnecessary to move forward the second barometer; but when this limit is exceeded, it ought to be brought forward at the completion of a day's work, and a fresh start for the next day's work made from the last visited point.

Subjoined is the form of field-book recommended for barometrical observations:

Date and Hour.	No. of Station.	Reading of Barometer.	Thermometer.		Deduced difference of Level.	Remarks.
			Att^d.	Det^d.		

The lines between which a comparison shall be instituted having been decided on, the process of levelling to obtain their sections is now to be proceeded with.

The instruments required are, a levelling instrument, (Troughton's or Gravatt's pattern is generally preferred,) a levelling staff, an iron tripod rest, and a 100-feet or Gunter's chain.*

It is essential that the instruments should be in adjustment, and the chain correct, or its error noted.

Taking then one of the lines to be tried, the course which it is to follow having been clearly pointed out, and a first portion laid out straight, or it may be curved, the levelling instrument is to be set up in a convenient position for taking the back and forward sights, and a general point of reference being established (which should be a bench-mark on some permanent object), the levelling staff is to be applied to the point of reference, and its reading noted and registered. The staff is then to be moved on to the forward station, where the reading being noted, and the distance measured and entered, the levelling instrument is carried forward; and the last forward now becoming the back station, the process is repeated until the section is completed. It is not necessary that the instrument should be set up in the line of section; it is generally more convenient that it should not be so; but it is most desirable that it should be as nearly as possible at equal distances from the back and forward stations.

In taking trial sections, it is to observed that minute accuracy in noting every trifling undulation would be a mere waste of time, as it is very improbable that the centre line of the intended railway will be followed; and a deviation of but a few feet from it may make a considerable difference in the levels. The levels of the crossings of all roads and streams, as well as of each change of general inclination, should, however, be observed, and the distances of the points apart limited to the range of the instrument, about 5 chains, beyond which the liability to error increases.

The following is the form of field-book recommended for trial sections. It appears sufficiently clear to render explanation unnecessary.

* Where the object of the measurement is confined to obtaining sectional areas and content, the 100-feet chain is much the most convenient; but where superficial areas are required, Gunter's chain is preferable. A Table of Equivalents will be found very useful in reducing the measurements, when either chain is used for both purposes.

Bearing or Angle of Direction.	Measured Distance Chains.	Rise.	Sights. Back.	Sights. Forward.	Fall.	Reduced Level.	Remarks.
						150·	Bench-mark on plinth
			3·44	6·72	3·28	146·52	of church: N. E.
S.E.	5·83	5·13	8·72	3·59		151·65	Angle assumed 150
250°·30	13·21	9·50	11·94	2·44		161·15	feet above datum
	16·54	7·63	10·65	3·02		168·78	level.
	18	8·11	9·89	1·78		176·89	
	18·36	12·22	14·32	2·10		189·11	Centre of road.
	23·10	8·47	11·66	3·19		197·58	Top of bank.
	29	7·20	9·78	2·58		204·78	
	36·59	4·53	7·24	2·71		209·31	
	43·20	6·33	8·86	2·53		215·64	
	44		1·23	11·53	10·35	205·34	Crest of ridge.
	45·08		0·98	12·76	11·78	193·56	Edge of brook.
S. by E.	45·90	8·51	12·76	4·25		186·07	Top of bank of brook.
267°·15	46·70	2·10	5·37	3·27		188·17	
	50	3·35	6·42	3·07		191·52	
	59·33	6·53	8·25	1·72		198·05	
	65·45	6·33	7·77	1·44		204·38	
	70	4·39	6·39	2·00		208·77	
			2·00	3·11	1·11	207·66	Bench-mark on gate-
	77·15	6·08	8·91	2·83		213·74	post at fork of lane.
	82·30	4·72	5·99	1·27		218·44	
	85·45		2·40	5·80	3·40	215·06	
	90·50		1·17	8·29	7·12	207·94	
		111·13	166·14	92·00	37·04		
		37·04	92·00				

Trial sections may also be run with great expedition, and with considerable, though less accuracy, by means of the theodolite. Though it is desirable that the instrument should be in good working order, it is essential only that the adjustments of the line of collimation, and of the transverse level, should be perfect.

The method of proceeding is to set the instrument up at the point of each general change of inclination, and setting a vane on a staff to the height of the levelled axis of the telescope (which may be made constant), to send it forward to the next point the relative level of which is required. The horizontal reading and angle of elevation or depression being then noted, and the distance measured to the surface of the ground, the horizontal distances and differences of level are readily obtained, making due allowance for curvature and refraction.

The other lines of trial sections having been also run (and it is desirable that they should all close on as well as start from the same point, that they may form a check on each other), in order to compare their relative merits, the sections should be laid down together on the same piece of paper, and with reference to the same plane of comparison, which it is convenient to assume at some distance below the lowest point to which the section descends. The sections may be coloured differently, the more readily to distinguish them. A scale sufficiently large on which to lay them down will be 4 inches to a mile for the distances, and 80 feet to an inch for the heights.

From these data the selection of the line to be adopted is to be formed, and in coming to the ultimate decision, on which the success of the scheme so much depends, the most careful deliberation is called for.

The line determined on is now surveyed, and following as near as possible the proposed centre line, a new series of levels is to be run.

The method to be pursued, and the form of field-book, do not differ from those described for running trial sections; but a greater degree of minuteness is required, and bench-marks should be established as often as fit objects and positions occur for making them on. These bench-marks are merely horizontal grooves (in this form usually) cut in some permanent object, as a mile-stone, the masonry of a bridge or other structure, a gate-post, the trunk of a tree, &c.; and their purpose is to serve as a basis for ulterior operations, or for testing the accuracy of the work by running check levels. In running check levels (and generally they are necessary), all that is required being the difference of heights, the distances need not be measured; and it is usual to pursue the most convenient route in connecting the bench-marks. Thus, on the plan (Plate I.), in order to check the difference of level between the bench-marks on the boundary stone at C and on the building at B, the road by the point A would be followed.

In the field-book for check levels, columns for the back and forward sights, and a column for remarks, is all that is required.

The section is now to be laid down on the plan according to the system termed 'Sectio-Planography,' required by the Standing Orders of Parliament, exhibiting the several cuttings and embankments; the cuttings being above and the embankments below the line, marking the centre of the proposed railway. This system is shewn on the plan (Plate I.) by the thin dotted line *a a a*.

A parliamentary section is also to be prepared, the scale for horizontal distances being required to be not less than 4 inches to 1 mile, whilst the vertical heights must be to a scale not less than 100 feet to an inch.

In the plan above referred to, with its corresponding sections, the scales are 6 inches to the mile for the horizontal distances, and 80 feet to 1 inch for the heights.

It is also required that a line shall be drawn on the section, representing the proposed upper surface of the rails; and also that at each change of inclination the height in feet and inches above a given datum level shall be marked; and that the rates of inclination shall likewise be shewn. These points will be made clear by reference to the section, (Plate I.)

The datum level generally referred to in this country is the Trinity high-water mark at London Bridge; other points more locally convenient may be referred to, but it is of general utility that all should be reduced to the same standard level.

The 'Standing Orders' further require that the height of the proposed railway under or over any turnpike-road, navigable river, canal, or other railway, shall be marked at the crossing; and also that any proposed change in the existing surface level of the river, &c., shall be shewn. (See Transverse Section, Plate I.)

Also, that where tunnelling is substituted for cutting, or arching for embanking, it shall be marked on plan and sections; and also that no deviation from the levels on the plan approved by Parliament, shall be permitted to exceed in any place 5 feet in open country, or 2 feet in passing through towns, without consent of the owners, trustees, or commissioners, as the case may be: and it is further decreed that no increase in inclination shall be made in any place to an extent exceeding 3 feet in 1 mile.

The sanction of the Legislature for the construction of the proposed railway having been obtained,—prior to entering upon the execution of the works, a contract or working section must be prepared. For this purpose, on the centre line accurately staked out, pickets should be driven in at each chain's length, and at each of them, as well as at other important points, the height of the ground obtained by levelling. These pickets should all be numbered, and every 5th or 10th one being a little larger,

may conveniently for reference be painted red, the others being painted white. Side-stakes, out of reach of disturbance in the progress of the works, may also be driven in at about every 10 chains, and the level of a cut upon each being noted, will be found very useful for reference after the breaking of the ground.

A form of field-book is appended. It will be seen on reference to it, that generally at each setting up of the instrument, the levels at several pickets may be obtained; and, except in rapidly falling ground, this will usually be the case. Some care is necessary in setting up the instrument advantageously to effect this; and it is to be remembered, that so far as the observations extend from the same station, the reading of the last forward sight is to be entered as the next back one.

From the reduced levels, the working section is to be laid down, the total heights from the datum line being employed as shewn in Plate II. The total height to the surface of the ground and the fixed altitude of any one point on the formation level being given, and the distances and ratio of inclination being determined, the depth of cutting or height of embankment at each point is directly and simply obtained.

This will appear clear on reference to the section, the horizontal scale for which is 5 chains to 1 inch, and the vertical 30 feet to 1 inch, which will be generally found sufficiently large for all purposes.

In connection with railway levelling is the setting out the side widths. When the ground does not fall transversely to the line, this is a very simple operation,—the half width of the railway + the depth of cutting, or height of embankment, multiplied by the ratio of their slopes, giving the distance to be set out from the centre line: when it does fall transversely, the degree of slope may be obtained when getting the centre levels, and entered in columns prepared for it in the field-book, (see form of field-book.) It will be necessary, however, that the side levels should be taken at some constant distance, say 50, or any other convenient number of feet. The half width may then be calculated from the formula

$$\frac{\sqrt{H^2 + (B + C\,r)^2} \times \left(C + \frac{B}{r}\right)}{C + \frac{B}{r} \pm H,}$$

in which

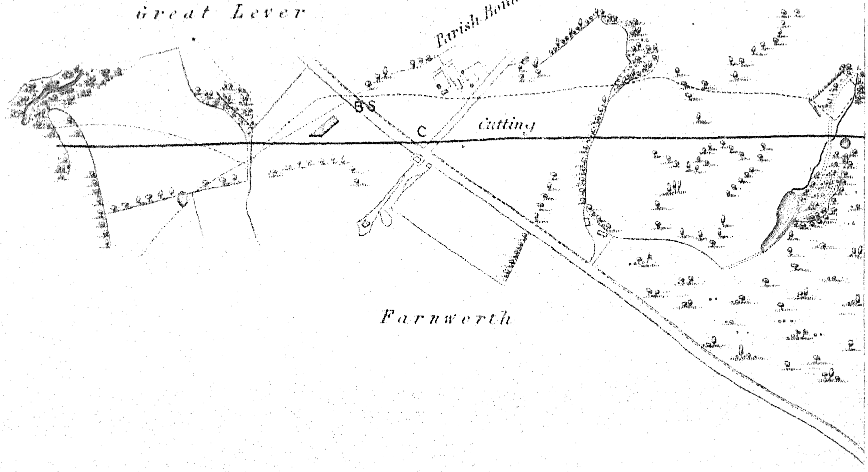
C = depth of cutting or height of embankment.
B = half width of railway.
r = ratio of slopes.
H = diff. of height between centre and side levels at computed half widths.

Due regard must be paid to the sign of H.

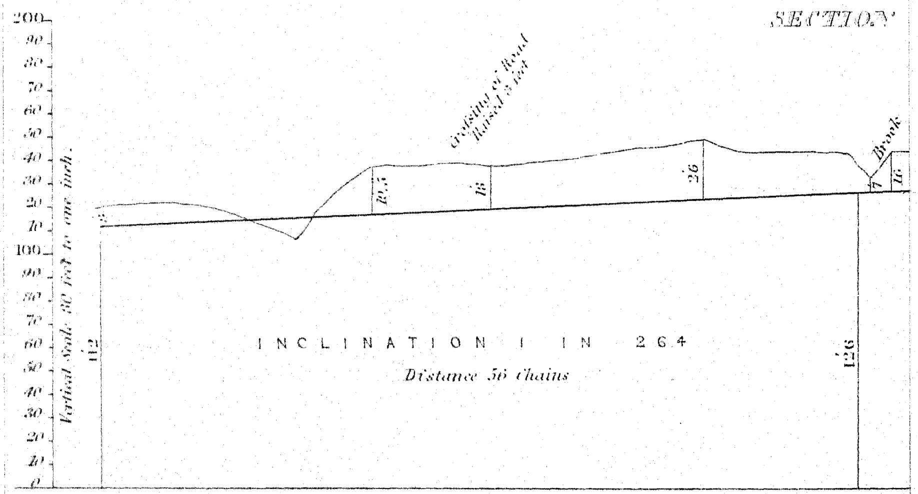
An expeditious practical method of setting out the half width at once on the ground is as follows:* the half width due to the several depths or heights on a level transverse section are computed and entered in a field note-book; the levelling instrument being then set up on the ground in a position convenient for the purpose, the difference of level between the centre and a point somewhat nearer than the computed distance, if the ground is falling, or further off, if rising, is obtained: this difference, multiplied by the ratio of the slope, gives a quantity to be added to or deducted from the computed half width, at which corrected distance, the staff being again applied, and the difference of level taken, by repeating the calculation a second approximation to the true point is made, which will in practice be found sufficiently exact.

The form of note-book is given below the form for the working section field-book.

* Described in Simms's 'Treatise on Levelling.'

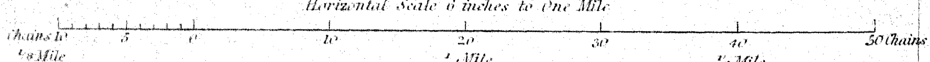


SECTION

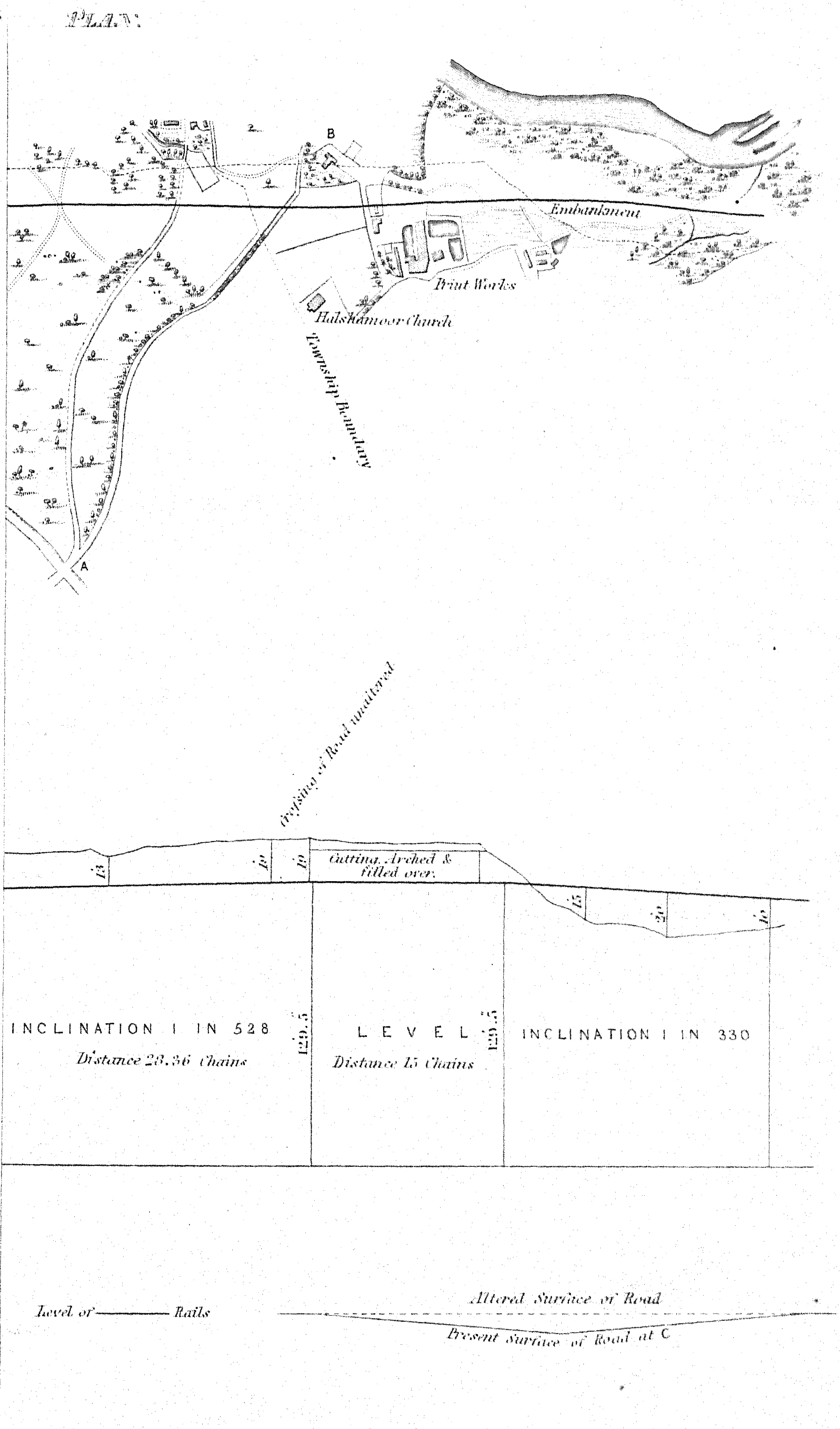


Datum Level Top level of an 18 feet tide by guage at St. George's Dock.

Horizontal Scale 6 inches to One Mile



London, John Weale, High Holborn, 1848.


PLAN.
B
Embankment
Print Works
Halshamoor Church
Township Boundary
A
Crossing of Road unaltered
Cutting, Arched & filled over.
13
10
10
15
20
10
INCLINATION 1 IN 528
Distance 28.36 Chains
129.5
LEVEL
Distance 15 Chains
129.5
INCLINATION 1 IN 330
Level of Rails
Altered Surface of Road
Present Surface of Road at C

J.W. Lowry fc.

LOOPHOLE.*—The term 'loophole' is understood to denote the opening in a masonry wall or stockade, for the use of musketry, as an embrasure is for that of artillery.

The nearly uniform dimensions of all infantry muskets of the present day, and a due attention to economy and convenience in building, have reduced the form of the loophole to two or three conditions, adapted to suit the purposes of defence.

It is usual to distinguish these by the direction of the exterior opening. Thus we call the loophole—vertical or horizontal, according as the exterior opening is upright, or the contrary.

The vertical construction is best adapted for sites where great vertical range is required, such as for the flanking of high scarps, or steep slopes, &c.

Under all other circumstances, the horizontal loophole will be found most effective and most convenient.† It affords greater advantages for defence, because, with great lateral extent, it combines sufficient vertical range to include the height of a man, which, under ordinary circumstances, is all that will be required.

The interior opening of the loophole can be of the same form in both these conditions, for a man to use his musket conveniently: it should not be less than 2 feet wide and 1 foot six inches high. Vertical loops are seldom constructed for more than one man to serve at a time; and in brick walls they are placed with their centres not less than 3 feet apart. Horizontal loops, on the contrary, can be constructed to contain two or even three men, the interior opening having an increase of not less than 2 feet per man.

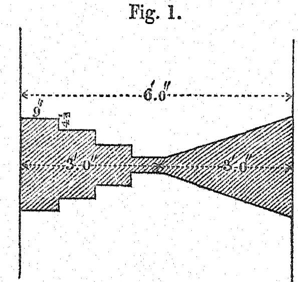
The extent of the exterior opening depends upon the range required, but its width should not exceed 3 inches, and the hole at the exterior should be at least 7 or 8 feet above the level of the ground at the outside, to prevent the loop being masked or fired into.

The length of barrel of a musket in our Service is about 3 feet 3 inches. As it is necessary that the muzzle should extend 3 inches outside of the loop, to prevent inconvenience from the explosion, it is evident that the ordinary form of loop is inapplicable to a wall of a greater thickness than 2 feet 6 inches, or at most 3 feet.

When this dimension is increased, it becomes necessary to make a corresponding modification in the arrangement of the loop.

Let us take 3 feet as a convenient thickness of wall, and construct the loop either vertical or horizontal, as before described.

Fig. 1.



Then, for any additional exterior thickness of wall up to 5 or 6 feet, the sides of the loop can be formed in successive courses of bricks, as described in Lieut.-Colonel Alderson's Memorandum in the eighth volume of the 'Professional Papers,' which is given at length in this Article.

But when the thickness of wall exceeds 6 feet, this method will be found inconvenient

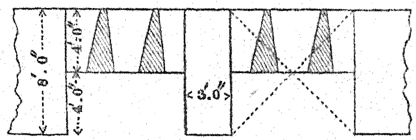
* By Captain Tylden, Royal Engineers.

† We do not concur; we conceive that the vertical loophole facilitates the command of the ground in front, and enables the soldier to deliver his fire with greater ease. In galleries for reverse fire and caponières to flank the ditches, the horizontal loophole may be preferable.—*Editors.*

on account of the great increase to the exterior opening; and in this case it is usual to form an arched recess in the interior, of whatever additional depth is required to make up the thickness of wall.

The recess may be made to contain three or four loops as may be convenient, and if the piers and arch be carried through to the exterior, the formation of the recess does not so much tend to weaken the wall.

Fig. 2.



The following excellent method of forming horizontal loops in brick-work has been suggested by Lieut.-Colonel Alderson, R. E.

"Horizontal loopholes present a much wider range of fire than vertical ones, for the space exposed, and in boundary walls, defensible barracks and guard-houses, reverse fires and caponières, are decidedly preferable.

"The present horizontal loophole is a cast iron frame, built into the wall so as to weaken it as little as possible. It is adapted for a wall three bricks thick.

"The same principle may be adopted in walls of any thickness.

Plate I. figs. 1, 2, and 3. "Fish-belly girders (*a, a, a*) are provided to strengthen the upper part of the loophole, and enable it to carry the wall above. Arches, however, may be turned as over window openings, if preferred. Half-inch iron will be sufficient for the sides and bottom of the frame.

"By giving the loophole the present form, it sets with great firmness in the wall.

"In reverse fires and caponières, whose object is the defence of the passage of the ditch, when the enemy is otherwise occupied than in returning the fire of them, external objects will be better seen by making the larger opening of the loophole outside, in which case the smaller opening may be increased from 4½ to 6 inches.

"In boundary walls, barracks, and guard-houses, the larger opening should be inside: it will afford in the two latter more light, and provide shelves for the occupants; and in the former it will present a smaller object, and make the opening higher from the outside.

"Loopholes should always be higher or lower than a man's height from the level of the ground immediately in front of them. When this cannot be effected, there should be a drop or ditch in front.

"Six feet is the length of the larger opening of the present loophole frame, which may be considered as a maximum, to be reduced according to circumstances. In towers or other works situated on high and commanding points with no level ground within range, the section described by fig. 4, Plate I., is recommended.

"These loopholes, though here represented of cast iron, may also be made of slate, or hard stone."

The above observations are chiefly applicable to the loophole when formed in brick; but when the wall is of stone, or the loophole itself set in stone in a brick wall, we are enabled, by a modified arrangement in the sides of the loop, to give much greater security to the defenders without entailing a great increase of expense.

late II. fig. 3. *a, b, c, d,* is a loophole to be served by two men, and requiring a horizontal range of 120°. A length of 6 feet for the interior opening will afford ample space for two men to serve at once. The thickness of wall is taken at 3 feet, and if the lines limiting the lateral range be produced, they will give an exterior opening of about 4 feet 6 inches.

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The nearly uniform dimensions of all infantry muskets of the present day, and a due attention to economy and convenience in building, have reduced the form of the loophole to two or three conditions, adapted to suit the purposes of defence.

It is usual to distinguish these by the direction of the exterior opening. Thus we call the loophole—vertical or horizontal, according as the exterior opening is upright, or the contrary.

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Under all other circumstances, the horizontal loophole will be found most effective and most convenient.† It affords greater advantages for defence, because, with great lateral extent, it combines sufficient vertical range to include the height of a man, which, under ordinary circumstances, is all that will be required.

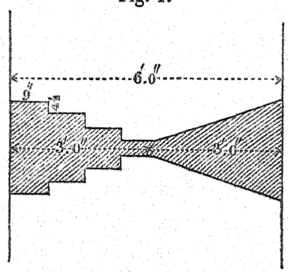
The interior opening of the loophole can be of the same form in both these conditions, for a man to use his musket conveniently: it should not be less than 2 feet wide and 1 foot six inches high. Vertical loops are seldom constructed for more than one man to serve at a time; and in brick walls they are placed with their centres not less than 3 feet apart. Horizontal loops, on the contrary, can be constructed to contain two or even three men, the interior opening having an increase of not less than 2 feet per man.

The extent of the exterior opening depends upon the range required, but its width should not exceed 3 inches, and the hole at the exterior should be at least 7 or 8 feet above the level of the ground at the outside, to prevent the loop being masked or fired into.

The length of barrel of a musket in our Service is about 3 feet 3 inches. As it is necessary that the muzzle should extend 3 inches outside of the loop, to prevent inconvenience from the explosion, it is evident that the ordinary form of loop is inapplicable to a wall of a greater thickness than 2 feet 6 inches, or at most 3 feet.

When this dimension is increased, it becomes necessary to make a corresponding modification in the arrangement of the loop.

Fig. 1.



Let us take 3 feet as a convenient thickness of wall, and construct the loop either vertical or horizontal, as before described.

Then, for any additional exterior thickness of wall up to 5 or 6 feet, the sides of the loop can be formed in successive courses of bricks, as described in Lieut.-Colonel Alderson's Memorandum in the eighth volume of the 'Professional Papers,' which is given at length in this Article.

But when the thickness of wall exceeds 6 feet, this method will be found inconvenient

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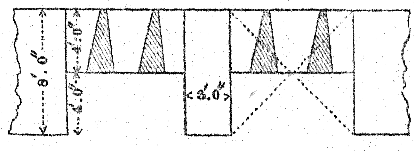
* By Captain Tylden, Royal Engineers.

† We do not concur; we conceive that the vertical loophole facilitates the command of the ground in front, and enables the soldier to deliver his fire with greater ease. In galleries for reverse fire and caponières to flank the ditches, the horizontal loophole may be preferable.—*Editors.*

on account of the great increase to the exterior opening; and in this case it is usual to form an arched recess in the interior, of whatever additional depth is required to make up the thickness of wall.

The recess may be made to contain three or four loops as may be convenient, and if the piers and arch be carried through to the exterior, the formation of the recess does not so much tend to weaken the wall.

Fig. 2.



The following excellent method of forming horizontal loops in brick-work has been suggested by Lieut.-Colonel Alderson, R. E.

" Horizontal loopholes present a much wider range of fire than vertical ones, for the space exposed, and in boundary walls, defensible barracks and guard-houses, reverse fires and caponières, are decidedly preferable.

" The present horizontal loophole is a cast iron frame, built into the wall so as to weaken it as little as possible. It is adapted for a wall three bricks thick.

" The same principle may be adopted in walls of any thickness.

Plate I. figs. 1, 2, and 3. " Fish-belly girders (*a*, *a*, *a*) are provided to strengthen the upper part of the loophole, and enable it to carry the wall above. Arches, however, may be turned as over window openings, if preferred. Half-inch iron will be sufficient for the sides and bottom of the frame.

" By giving the loophole the present form, it sets with great firmness in the wall.

" In reverse fires and caponières, whose object is the defence of the passage of the ditch, when the enemy is otherwise occupied than in returning the fire of them, external objects will be better seen by making the larger opening of the loophole outside, in which case the smaller opening may be increased from 4½ to 6 inches.

" In boundary walls, barracks, and guard-houses, the larger opening should be inside: it will afford in the two latter more light, and provide shelves for the occupants; and in the former it will present a smaller object, and make the opening higher from the outside.

" Loopholes should always be higher or lower than a man's height from the level of the ground immediately in front of them. When this cannot be effected, there should be a drop or ditch in front.

" Six feet is the length of the larger opening of the present loophole frame, which may be considered as a maximum, to be reduced according to circumstances. In towers or other works situated on high and commanding points with no level ground within range, the section described by fig. 4, Plate I., is recommended.

" These loopholes, though here represented of cast iron, may also be made of slate, or hard stone."

The above observations are chiefly applicable to the loophole when formed in brick; but when the wall is of stone, or the loophole itself set in stone in a brick wall, we are enabled, by a modified arrangement in the sides of the loop, to give much greater security to the defenders without entailing a great increase of expense.

ate II. fig. 3. *a*, *b*, *c*, *d*, is a loophole to be served by two men, and requiring a horizontal range of 120°. A length of 6 feet for the interior opening will afford ample space for two men to serve at once. The thickness of wall is taken at 3 feet, and if the lines limiting the lateral range be produced, they will give an exterior opening of about 4 feet 6 inches.

It will now appear that if the lines *a c—b d* were to form the sides of the loop, the greatest protection will ensue to the defender when the opening at *e* is as small as possible.

It is necessary, however, that both men should be enabled, if required, to fire direct to the front; and a due regard to light and ventilation will not allow of this opening having a less length than 2 feet, so that the vertical area of the opening at this point will be about 2 feet by 11 inches high.

To insure resistance against a musket-ball, and to give proper strength to the side of the loop where a soft stone is used, the thickness *f g* should not be less than 6 inches, though it will be of advantage to diminish this dimension whenever a harder material will allow of it.

The sides *g b—h c* forming portions of the lines limiting the lateral range of the loops, the lines *k f—l i* are directed on the angles *h* and *g*, and lines drawn from *a* and *d*, to intersect them at *k* and *l*, and forming an angle of 40° with *a f* and *d i*, it being assumed that a bullet will not effectually reflect from a wall at a greater angle.

On examining this construction it will be evident that no bullet can possibly reflect into the interior after striking the side of the loop, except upon the small portions *f g*, *h i*; and that while the range of 120° is preserved, the vertical space through which a bullet must pass to enter the interior is only 2 feet long by 3 inches high.*

Plate III. figs. 1, 2 and 3. A construction something similar to that just described will be found in a Paper by Lieut.-Colonel Ord, in the eighth volume of the 'Professional Papers,' and drawings of which are given in Plate III. figs. 1, 2 and 3.

"Figs. 1 and 2 represent a simple horizontal loophole for two men to fire through. They should be, when practicable, made of cut stone throughout: if of brick-work, the head should be arched, as shewn by dotted lines in fig. 4, the sides of common brick, and the holes of good hard Dutch clinkers or fire-bricks (when manufactured of a hard nature), and set in cement.

"All the four sides have one break on return, offering an important obstacle to balls from without, whether from a direct fire, or after having been reflected from some other object.

Plate III. "The zigzagged loophole (fig. 3) is a plan that may be adopted with great advantage, where it is desirable, or even convenient, to have the mouth of the loophole towards the enemy, and which, in consequence of the numerous 'facets' covered with sheet iron, will be found to afford scarcely less security than the plain-sided one, with the narrow opening outwards."

The following description of Lieut.-Col. Ord's loopholed window for defensive barracks, &c., and other buildings requiring a reasonable supply of light and ventilation, is taken from the same Paper.

"Figs. 4, 5, 6, 7, represent the loopholed window. The dimensions, when the window is to be used as a loophole, are the same as those in figs. 1 and 2, Pl. III., and this is effected as follows: a wrought iron abattant, or falling shutter, is attached to the head of the iron window frame by means of a pivot or hinge, the two ends working in iron eyes or rings. The pivot is of round bar iron, with the sheet iron forming the abattant riveted to it: this abattant is lowered to the iron rests (see fig. 7), and thus forms a very complete loophole. When employed as a window, the

* The dimensions in the diagram are merely assumed to illustrate the principle, which is applicable to any variation either in the thickness of wall or size of loop.—R. T.

abattant is raised by winch-handles, which are fixed on the square ends of the pivot or hinge, and, being bolted, remain continually up.

"The iron sashes are removed for action, and the loophole is then clear.

"By examining fig. 7, it will be clear that no injury can be done to the defender by shots between the abattant and the head of the window above it, unless the firing should be of such a nature that an ordinary loophole would be almost destroyed by it.

"Plates are riveted to the angles of the abattant to strengthen it. The necessity for them, and their dimensions and numbers, would be left to the discretion of the Engineer, as the strength required would of course vary according to the fire likely to be brought upon it, which would depend on the locality.

"The loopholed window should also be in cut stone, whenever practicable.

"This window may be lengthened to 6 feet when necessary, this length being the maximum."

Great difference of opinion exists in our Service with regard to the comparative advantages of loopholed fire and that of the ordinary parapet; but in sites liable to be commanded within musketry range, and unexposed to the fire of artillery, and for the close defence of the ditches, &c., of permanent works, the loophole presents most unquestionable advantages.

The general application of loopholed fire in all fortresses recently erected or in course of execution on the Continent, together with the attention paid to the direction and construction of the loops themselves, afford ample evidence on this point. It would appear that the vertical construction is almost universal in these works.* Figs. 1 and 2, Plate II., are descriptive of the arrangement of some loops at Grenoble, and form a good example for the adjustment of vertical loops upon uneven ground.

Respecting the local distribution of loops, no positive rules can be laid down where every thing depends upon the nature of the site. The following observations may perhaps be of general application.

Where the loops are formed in long continued walls properly flanked by artillery or musketry, such as in the gorges of large works, they can be dispersed at longer intervals, in proportion as the command of the ground immediately in front of them is of more or less importance.

When, however, the interval between them exceeds 7 or 8 feet, the fire becomes weak and futile; and it will be found of advantage in these instances to concentrate the loops in detached numbers towards those points most necessary to command, rather than to pierce the wall equally throughout its whole length; because, in the former case, the men will rush at once to the points most necessary to defend, and will be more under command than when detached singly at longer intervals.

On the contrary, in caponières, reverse fires for the defence of the ditch, and where the object will be to *prevent* the passage of a large body of men, the loopholes cannot be in too great number, or too closely approximated to each other; provided always that sufficient space is allowed on each side and in rear of the loophole for one man to use, and another to load his musket, in rear of him: and it may be here observed that 2′ 6″ to 3′ from centre to centre of the loops, and 6 feet width of passage in rear, are the minimum dimensions that will answer these objects.

When there are any additional obstacles in the ditch, such as the 'cunette' of a permanent wet ditch, or palisades, or other impediments in the ditches of Field Forts,

* From Captain Maurice's 'Essai sur la Fortification Moderne.'

It will now appear that if the lines *a c*—*b d* were to form the sides of the loop, the greatest protection will ensue to the defender when the opening at *e* is as small as possible.

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* From Captain Maurice's 'Essai sur la Fortification Moderne.'

it is of course advantageous to concentrate a considerable portion of the loopholed fire immediately in front of such obstacles; and, indeed, the same advantage may be obtained for all loopholed walls, by the construction of abattis, &c., at a convenient distance in front of them: but every loophole should be laid out with reference to locality and its specific object, like an embrasure.

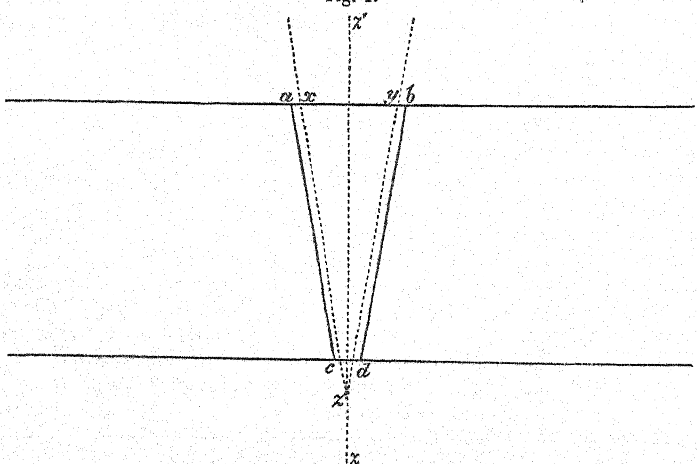
Many distinguished Officers in our Service can state from experience that no obstacle is more terrific or appalling to troops than a strongly constructed palisade or other impediment in the ditch, flanked by a powerful loopholed fire, well sustained and well directed.

Memorandum.—For the hasty construction of loopholes in the field, the reader is referred to 'Field Fortification.'—R. T.

Note on Embrasures.—As the construction of embrasures varies without reference to localities or any specific conditions, the following observations are offered upon the principles on which they should be constructed.

We are taught that the *interior* opening at the genouillère for cannon should not be less than 2 feet 2 inches, and at the exterior part of the *embrasure* it should be half the thickness of the parapet: these dimensions apply to earthen parapets that are more than 9 feet thick. When less, and the parapets are built of masonry or brick-work, the following will be found more suitable, by giving the external width of the embrasure one-third of the thickness of the parapet, plus the *interior* opening: for example, if it is 6 feet thick, the exterior width will be 4 feet 2 inches; and if 9 feet, 5 feet 2 inches. These normal dimensions give the minimum opening to the *embrasure* to afford the maximum cover to the men, gun, and carriage, and within which is the smallest space the explosion will permit, as explained by the lines *a c* and

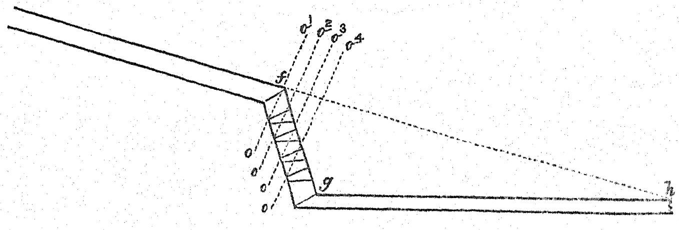
Fig. 1.



$b\,d$ perpendicular to $z\,z'$, in fig. 1. But the line of fire only extends to the triangle, $x\,z\,y$; and if the muzzle of the gun is directed by the gunner beyond, he will destroy his own cover by blowing away the cheeks of the embrasure.

Although these rules are based upon certain principles, yet their application is not arbitrary, and there are exceptions which should be considered in laying out the embrasure; as for example, when the battery is exposed only to the oblique fire of an enemy, in flanks and re-entering angles, to follow the normal dimensions is contracting the power of your artillery, to the loss of flanking fire, as explained in fig. 2, where it is shewn that the line $g\,h$ and the gate h are not seen from the embrasures.

Fig. 2.

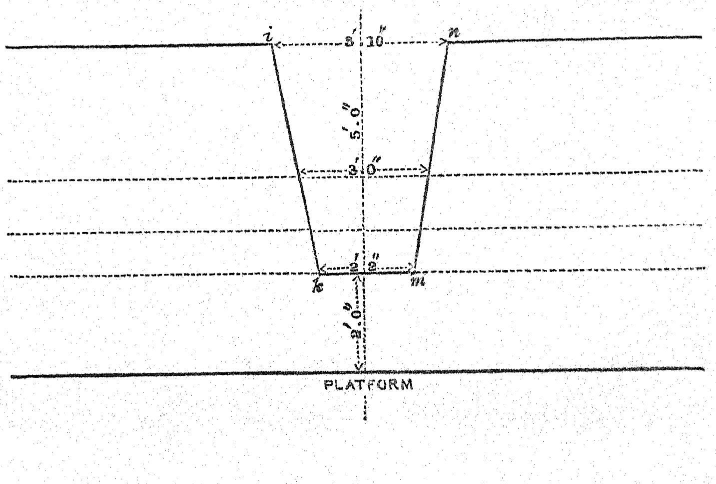


Now as the interior may be only exposed in the directions $o\,o$, it is unnecessary to give the minimum opening, and as this deficiency of flanking fire may expose a fortress to a coup-de-main, it is time enough to contract the embrasures in the flanks when the counter batteries of the besiegers are about to be established.

To what extent local circumstances will permit a deviation, rests in the judgment of the Engineer; but an extension to the angle $x\,z\,y$, fig. 1, will preserve the cheeks of the embrasure, and add to the scope or lateral breadth of the fire of the artillery.

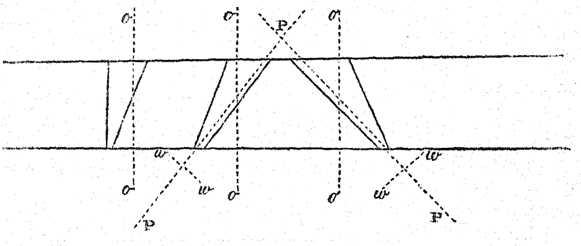
When a gun is mounted upon a travelling carriage of which the genouillère is 3 feet high, the interior opening at the genouillère may be 2 feet 6 inches, and for the dwarf traversing platform 3 feet, and a corresponding addition to the exterior width, giving the cheeks of the embrasure a slope of $\frac{1}{6}$th the height, as in fig. 3.

Fig. 3.



Oblique Embrasures are occasionally pierced in parapets for particular objects; but except under circumstances explained in fig. 2, they are objectionable, as shewn in fig. 4.

Fig. 4.



When the parapets are exposed to a direct fire from an enemy, and the embrasures are cut obliquely for some especial purpose on the lines P P, the following difficulties occur: the parapets on the lines *o o* become too thin, and are not shot-proof; the interior is too confined, and is liable to be blown away by the firing of the guns; increased, too, because they cannot be run up on the platform, the width of the carriage and space required for the men preventing it, as shewn on the dotted lines *w w*.—G. G. L.

ADDITIONAL NOTE ON EMBRASURES.

The simple form of embrasure still in general use, and which is merely an extension of the simple form of loophole, has come down to us from a remote epoch, and appears to have been adopted on the following principles: 1st. By a narrow internal opening to keep the men as much as possible under cover. 2nd. By a wide external opening to give as much lateral range as possible, consistent with the stability of the parapet. The actual range attained with a parapet of 18 feet thickness and 9 feet external aperture, does not extend over more than 27°; but on the old system of Vauban, of placing the embrasures 18 feet from centre to centre, four guns could be brought to bear on any point of the ground before them at 89 yards, three at 67 yards, two at 45 yards; so that, considering the proper lengths of curtains and lines of defence, it may be justly said that in this, as in other arrangements of the early masters, the dimensions adopted were selected on principle. 3rd. In an 18-feet parapet, the distance from the muzzle of the gun to the cheeks need never be less than 1′ 9″, as the gun ought never to be laid close to any cheek when firing parallel to it. 4th. The funnel shape, expanding outwards, greatly facilitates the escape of the elastic gases, smoke, &c.; and this is an additional reason for making that portion of a loophole, in thick walls, which is beyond the muzzle of the musket, expand outwards. It is evident, therefore, that the early form of embrasure, however simple, was not established without reason, and possesses many advantages. Occasionally, in very ancient fortresses, a casemate was formed in the parapet, and the gun advanced into it, the rear being open; a plan which had its advantage in cases where the parapet was unusually thick, and the range would have been much diminished without an inordinate extent of aperture; and, in modern times, Montalembert has adopted this arrangement, with a view to obtain increased range with diminished exposure. On his plan, the pivot of traversing platforms is, in a 6-feet parapet, carried forward to about 2 feet from the front, and a range of 60° is obtained with an opening of 3 feet 9 inches; whereas the same range would have required an opening

PLAN SECTION AND ELEVATION OF AN HORIZONTAL LOOP HOLE.

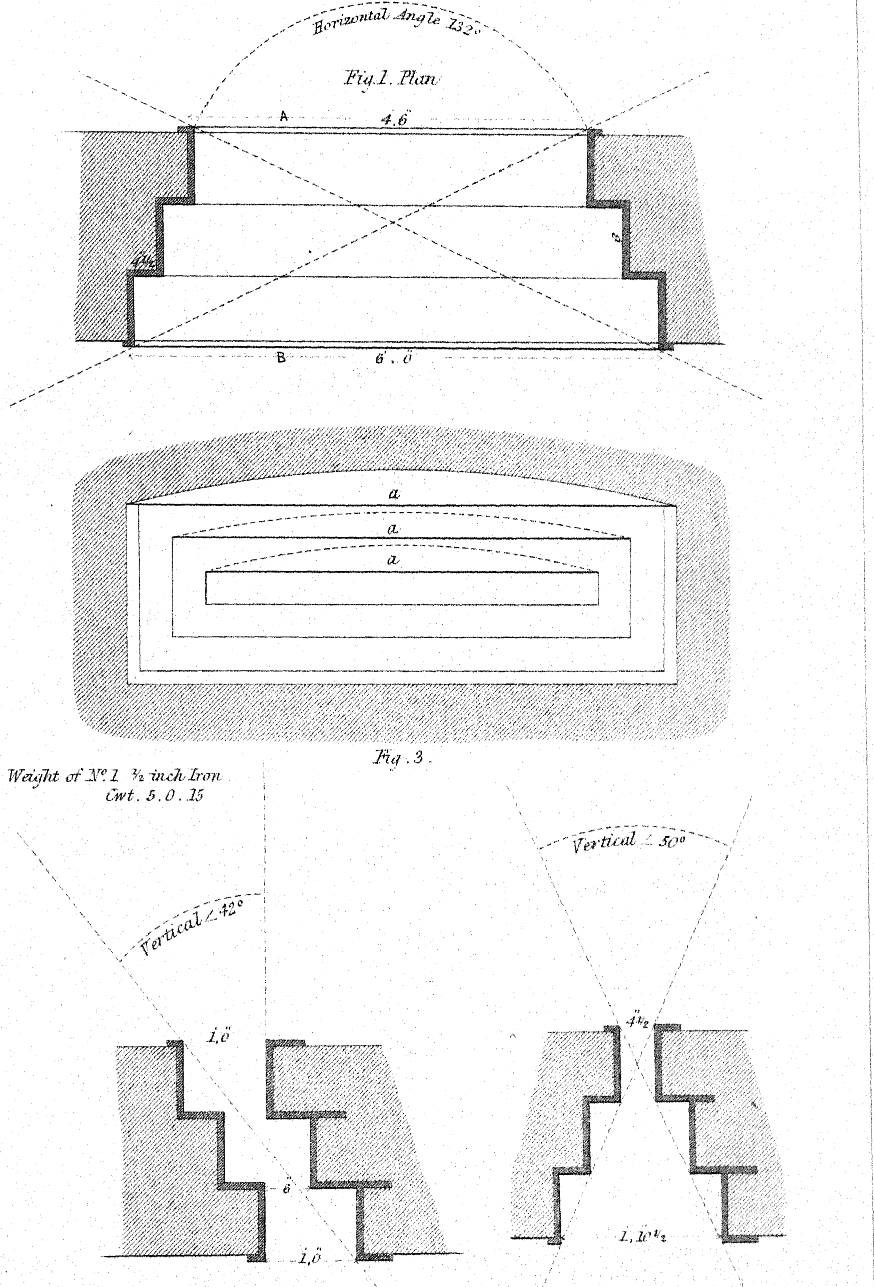


Fig 4. Section of a Loop-hole for Hill Forts.

Fig. 2. Section on A B

J.W. Lowry fc.

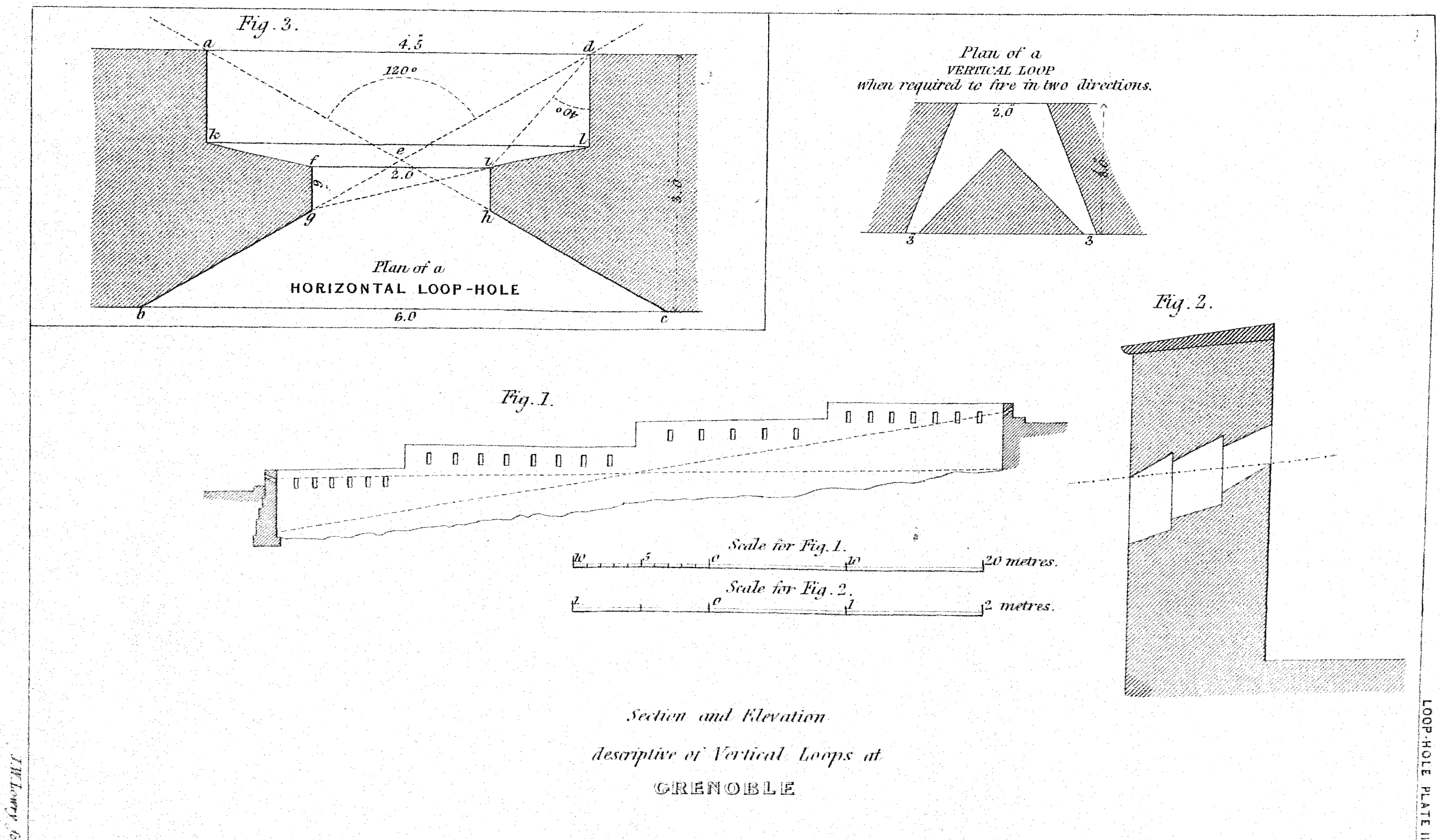
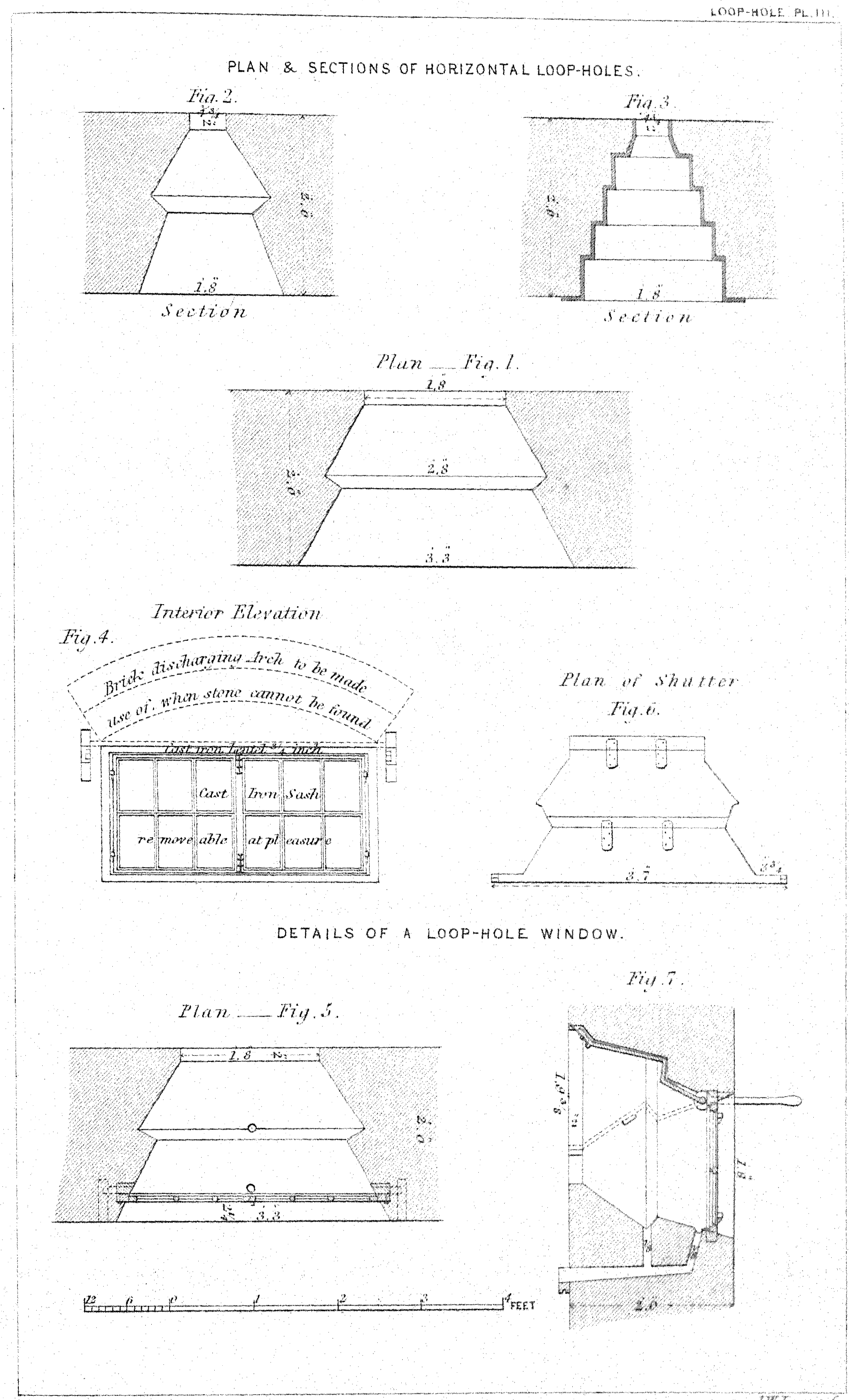


Fig. 3.
a
4.5
d
120°
40°
k
l
e
f
i
2.0
6.
8.0
g
h
Plan of a
HORIZONTAL LOOP-HOLE
b
6.0
c
Plan of a
VERTICAL LOOP
when required to fire in two directions.
2.0
3
3
Fig. 2.
Fig. 1.
Scale for Fig. 1.
10
5
0
10
20 metres.
Scale for Fig. 2.
1
0
1
2 metres.
Section and Elevation
descriptive of Vertical Loops at
GRENOBLE
J.W. Lowry fc.



J.W. Lowry fc.

London, John Weale, 59, High Holborn, 1847.

of 8 feet, had the pivot been placed, as at Cherbourg, in the parapet but only 1 foot 6 inches from the interior of the wall. This appears a great advantage, but there is a disadvantage connected with it in actual service which has been overlooked; namely, that the wall must be cut away in a corresponding degree in the rear, to permit the gun to traverse so that the carriage is brought, when trained to either side, within the parapet; and even after recoil, the inconvenience of loading must be considerable. Montalembert intended, however, his embrasure merely for casemates; but Lieut. Penrice proposes its application to parapets of greater thickness, in order to replace entirely the old embrasure; and in that case the difficulty pointed out would be still greater, and the extent of parapet in the rear required to be cut away, in order to admit of ready manipulation, much augmented.

In the ninth volume of the 'Corps Papers,' it has been proposed to modify still further the opening of Montalembert's embrasure, by adopting a cheek of more than one plane, so arranged as to prevent a shot entering by ricochet from its surface. On this latter point, there is much misapprehension from confounding the ricochet angle with low charges with that of high charges; and as embrasures are more exposed to the fire of guns with full service charges than to the true ricochet fire with low charges, the precaution directed against the latter is unnecessary against the former. By the experiments carried on at Metz, it has been shewn that a 12-lb. French shot with a charge of one-half its weight began to ricochet only at 20°; and with one-third only at 25°; and that in each case there is penetration to the extent of nearly 6 inches, the ball being reflected at a considerably higher angle by scooping out the masonry, and in so doing, losing its velocity to such an extent as to be capable of doing little subsequent injury. The great evils are, the ruin of the embrasure, and the destructive effects of its splinters; and these are perhaps best guarded against by preserving the simple earthen embrasure, strengthening only the throat by a concrete backing extending inwards for about 3 feet, to receive the shock of the shot after it has penetrated the earth. Without therefore wishing to check improvements in loopholes, or in embrasures, a doubt may be fairly expressed whether the advantages expected from the more complicated forms proposed are really equivalent to the disadvantages which attend them in service; and whether the simple loophole and embrasure, properly applied and arranged, has not yet a practical superiority over those proposed to replace them.—J. E. P.

M.

MACHICOULIS.*—*Machicoulis galleries* are constructed over the entrance to a building or enclosure, or over parts where an opening is liable to be effected by crow-bars, or by firing a charge of powder, &c. Their use is to enable a perpendicular musketry fire to be directed upon the enemy outside, and to facilitate pouring down melted lead or other missiles upon them.

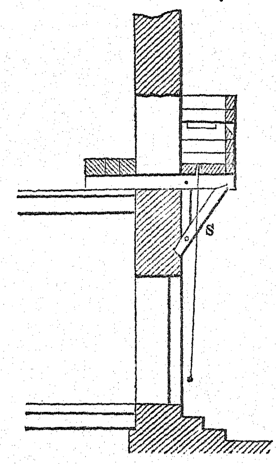
Blockhouses are often constructed with the upper stories projecting all round, so as to afford them this means of defence (*vide* 'Blockhouse'); and in the Article on

* By Captain Bainbrigge, R. E.

'Guerites' will be found an account of the application of machicoulis galleries to salient angles.

When placed at one side of a building or enclosure, an opening large enough for a man to get through is made at least 8 feet above the ground outside, and holes are also broken through the wall on each side, and level with the bottom of the first, to admit of strong beams being thrust through, so as to project horizontally 3 feet, if possible, outside; the outer ends of which must be supported by struts (marked S in the figure), resting against notches made in the wall, or by securing their inner ends by heavy weights or ties: across these beams, planks are laid forming a floor, with an interval 4 inches wide for firing through; and round the front and sides of this platform a parapet of wood or of iron plates must be built, so as to cover the men whilst firing, in which loopholes may be formed. This may be made of oak planks 2 inches thick, covered with wrought iron plates $\frac{1}{8}$th inch thick; and the thickness of other materials required are given in the Article on 'Barricades.'

Fig. 1.—Section of a Machicoulis Gallery.



Scale 10 feet to an inch.

An ordinary iron balcony forms a very good frame-work for a machicoulis gallery, as shewn in Plate I. 'Defence of Posts;' and it has been suggested that by fixing iron shutters in front of embrasures, so as to form a salient angle, and projecting beyond the wall, they may be used to fire from upon an enemy at the foot of it.

Machicoulis galleries, built of brick resting upon stone corbels, are often applied to Martello towers for the defence of the doors, or over re-entering angles of fortifications when they are badly flanked, but they are liable to be destroyed by a single cannon-shot, unless their walls are supported by massive arches, and made 3 or 4 feet thick.

Note on Machicoulis—Frequently used in the defence of escarps and towers; and St. George's Tower, at Windsor Castle, is an example. Captain Nelson, R.E., has applied them to a project in the 7th volume of 'Professional Papers,' in the Article on Coast Defences; and the annexed diagram will explain how they may be applied advantageously to lines of walls on the edge of precipices, banks of rivers, and on sea lines, where it is desirable to see the foot of the walls in particular circumstances, when they are not exposed to the fire of heavy artillery, and the ground for the line of wall too narrow to permit a flank defence. See fig. 2 and 3.

Fig. 2.

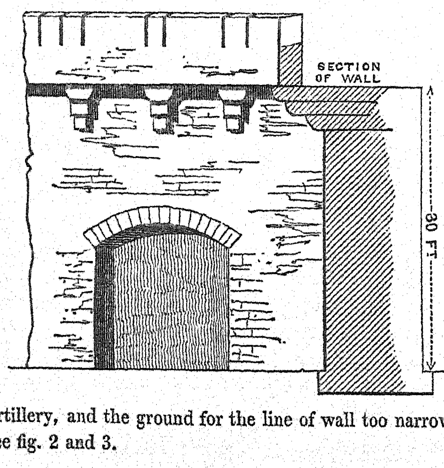
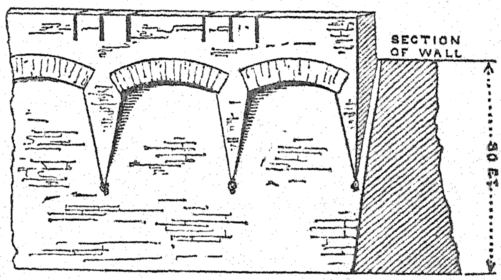
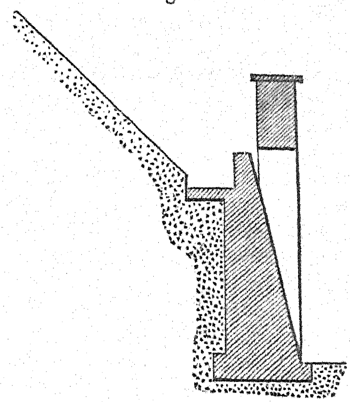


Fig. 3.



Capitaine Emile Maurice, in his 'Essai sur la Fortification Moderne,' applies the machicoulis to the chemin des rondes, as in fig. 4.

Fig. 4.



The entrance of towers and small forts without flanks should each have a machicoulis over the gateway or drawbridge; for small garrisons are frequently intimidated by the miner fixing a petard or bag of powder to the gate or bridge, and are inclined to surrender without sufficient cause. These works should always have a supply of filled sand-bags ready to be placed in the internal recesses of the doors and windows, equal to the interior thickness of the walls, which would prevent any ill effect of the explosion.

MAGAZINE.—*The Construction of Gunpowder Magazines** should have reference to their object, whether they are required as a dépôt, entrepôt, or for the supply of coast batteries, forts or fortresses: in the latter cases they should be bomb-proof. It is conceived that if they hold 500 rounds per gun, that quantity will be the most convenient for supply; and no magazine should contain more than 1000 barrels. In a fortified place, armed with 100 pieces of ordnance, this arrangement would require five magazines.

When it is found convenient in fortified places to place the magazines in detached sites, such as the centre of empty bastions, or open spaces within the enceinte, for the preservation of the powder previous to investment, or to a probable attack by sea or land, there are various ways of constructing them: among the earliest patterns followed are those of Vauban and Belidor.

Major-General Fanshawe appears not to approve of Vauban's or Müller's external buttresses, but would prefer having the external lines free from *corners*, which always generate damp, and instead would place them within, and groined into the main arch, and that the arches should extend to the outside of the end walls. When a series of parallel apartments are necessary, Major-General Fanshawe prefers their

* Compiled by Colonel Lewis, R. E.

being connected by groined arches, and he is an advocate for as much areal capacity as possible. Those at Tipner are an example of this description of magazine.

He considers, likewise, that no building, but especially a magazine, should be erected over a pit or excavation, unless there be a still lower and well-drained area around the contour of the building itself. Whitewashing with lime is objectionable, as lime attracts moisture; but if there should be causes of internal damp, small parcels of lime may be placed, to attract the damp, near the ventilators.

Major-General Pasley, in his work on Elementary Fortification,* observes that "powder magazines are usually provided with double doors and window-shutters, which are made of thick materials and covered with copper. The air-holes, both inside and out, are covered with copper, and copper-plates having a great number of small holes perforated in them. No iron or steel are ever permitted in the construction of powder magazines.

"Sometimes magazines have been formed with groined arches, that is to say, with two sets of arches, of equal height or nearly so, intersecting each other at right angles. In this method there is a saving of materials, and a greater interior space may be gained, because, instead of intermediate pier walls, extending in a continued line from one end of the magazine to the other, as in the former construction, there are only small pillars of about 4 or 5 feet square at the utmost, which may be placed at considerable intervals apart, and from which the groined arches spring in contrary directions. This construction has, however, been seldom used, being less simple and weaker than the former mode.

"With respect to the roofs of magazines and other bomb-proofs, which are not covered at top with some feet of rubbish, like those of casemates, it is prudent on that account to add to the thickness of masonry, in order to make them equally secure against shells; but the same precautions against damp are unnecessary, for the common slates or tiling, &c., used in dwelling-houses, are quite sufficient, provided that the ridges and gutters are leaded. Much, however, depends upon the pitch of the roof, which ought to be rather steep than otherwise; the low pitch recommended by some architects, for the sake of beauty, being unfit for northern climates."

Powder Magazines have lately been erected in Germany which bring the buttress within: this mode of constructing magazines appears to have the advantages of groined arches, without the disadvantages alluded to by General Pasley.

When magazines are isolated, for the advantages of a free circulation of air, and preservation of the powder in time of peace, the German construction should be adopted, to hold 4000 or 5000 barrels, and distributed, when an attack was threatened, into small magazines. The late Colonel Williamson, of the Royal Artillery, in his Notes, as published in the '*Minutes of Proceedings of the Royal Artillery Institution*,' observes, "In cases of siege it is usual, and indeed necessary, to place splinter-proofs and traverses before the doors of the principal magazines of a fortress; and the windows, especially those on the side of the country, are frequently built up or shut up with logs of timber. In this case the magazines are very dark, and indeed many magazines, situated in the towers of old fortifications, have scarcely any light at all: it is consequently necessary to make use of Muscovy lanterns, which should invariably be held by a non-commissioned officer or some trusty person. The door of the lantern should never be on any account opened in the magazine; and the candles should be of wax, as when of tallow they frequently require snuffing. Splinter-proofs before the doors make them very dark, and a person

* Second edition, p. 372, &c.

upon entering fancies himself in complete darkness; but after a short time things are readily distinguished. The men, therefore, at work inside of the magazine ought always to remain inside, and those outside never to enter, but lay the barrels down or receive them at the doorway, besides a third party stationed at the entrance, and communicating with the other two.

"Powder magazines are usually divided into certain spaces, called bays, by wooden posts or uprights connected together at top and bottom by open frame-work: passages are left between the parallel bays and at the ends, of 2 feet 2 inches wide. In all powder magazines it ought to be an invariable rule, that one of the bays be empty, for the sake of shifting the powder, which ought to be frequently done. The empty bay is to receive the barrels from a full bay; and this bay, just emptied, is to receive those of another full bay, and so on; so that the last bay emptied will remain so. When shifting the powder, the situation of the barrels must be changed: those which were at the top tier are placed in the bottom tier, and those which were at the bottom in the top, by which means they are relieved from the great pressure which was on them when they were lowest."

Since the introduction of concrete in foundations, it is now the practice in building powder magazines, or in renewing the flooring, to spread concrete throughout, so as to prevent damp rising from the ground, and to build the walls which bear the flooring joists upon it, to such a height that a current of air will pass between these low piers. The ground between the walls of all magazines and the surrounding wall should be paved and kept clear of weeds.

The Position of Gunpowder Magazines, and the Security of the Powder, must also have reference to the wants of the Service: for dépôts, entire separation from other buildings, and freedom from all risk of fire, are the important considerations. The next points are the conveniences of transport by *sea* or *land*. It does not appear essential that the magazines for dépôts should be arched: the dépôt at Marchwood has a timber roof like a store, and the buildings are dry, and the powder in excellent order. The Storekeeper of this excellent establishment suggests that the roofs of magazines of this description should be of one span, to avoid lead gutters, as they frequently crack, and admit rain and snow: the doors should be placed north and south, the windows east and west, and open inside, with wire-guards outside: the spouting should be of copper, and not of wood. He prefers that barrels of powder should contain 90 lbs., and not 100 lbs., as now ordered, as the former quantity allows the powder to fall back into single grains every time it is moved. Magazines should never be opened in rainy or damp weather, if it can be avoided.

The Position of Magazines in Fortresses.—Some difference of opinion exists with Artillery Officers in this respect. It is conceived, therefore, that magazines for the general supply of a fortress should be detached from the ramparts, in an airy site, in the empty bastions, in a work entirely enclosed by them; or in maritime places, in sites contiguous to the embarkation and disembarkation of stores; and that during a siege the powder should be placed under the ramparts, perfectly secure from an accidental explosion from the enemy's artillery, and the passages to the magazine well blinded.

Expense Magazines, as explained in the Notes of the late Colonel Williamson, of the Royal Artillery, published in the '*Minutes of Proceedings of the Royal Artillery Institution at Woolwich*,' should be "much smaller than powder magazines: when possible, they should be bomb-proof, but in general they are not so. In a fortress, there ought to be an expense magazine to each bastion and battery, though this is not always the case: they generally only contain made-up ammunition, that is, cartridges for the ordnance in the bastion or battery, at the rate of so many rounds per gun, to

which is to be added the tubes, port-fires, &c.: sometimes the side-arms, and case-shot, &c., are kept there, and are usually under the care of the Artillery Officer in charge of the district. They are often made under the earthen ramparts of fortifications, with a cut or passage made into them in the interior slopes: they ought not, however, to be made until a siege be apprehended; for as they are only temporary, and constructed of wood-work, from the centre they are often damp, and the wood decays.*

"When there is only one expense magazine for several batteries, or when a battery consists of only two or three pieces, it is usual to have on each battery *Portable Magazines:* they are wooden boxes covered with canvass, and of such a size as to be carried from place to place; they are sometimes on wheels, and sometimes without: in the latter case, they ought always to be placed on skidding, to keep them off the ground, besides having ledges on their bottoms. In these is contained a certain number of cartridges for each piece in the battery, together with tubes and port-fires: the side-arms, handspikes, &c., are in such case placed in a small shed built against the interior slope of the epaulement, to defend them from the weather."

In conclusion, it should be explained that magazine, as a military expression, always means *powder magazine;* and when military buildings contain other materials, they are termed *stores.*

MANŒUVRES OF CAVALRY.†—The British Cavalry of the present time is composed of two kinds, 'Heavy' and 'Light.'

1st. The 'Heavy Cavalry,'—Cuirassiers, Dragoon Guards, and Dragoons.

2nd. 'Light Cavalry,'—Light Dragoons, Lancers, and Hussars.

The heavy cavalry should be employed in actions of shock, and movement en masse.

The duties of light cavalry should be, reconnaissances, outposts, pickets, patroles, &c.

The instructions for cavalry should be concise and simple, and entirely founded on the practice of actual warfare; for the more theory is identified with practice, the better.

The dismounted drill of the dragoon is the means of teaching and preserving the recollection of the mounted manœuvres, without harassing the horses, and is now very properly executed by the same words of command.

There are three distinct paces in cavalry; viz. the 'walk,' about four miles per hour; the 'trot' of about eight miles per hour; and the 'gallop' of eleven miles per hour.

1st. The 'walk,' which is the pace of route, and when on service, ought not to be exceeded, it being sufficiently quick for the movements of an army (unless upon an emergency), as the average weight of a dragoon is upwards of 18 stone, not including rations and forage, which, for one day's consumption, is about 28 lbs.

2nd. The 'trot' is the best pace for manœuvre: it enables a column or line to preserve its ensemble.

3rd. The 'gallop,' which embraces the 'charge,' is the pace of action, or for quick formations preparatory to it; at this pace the horse is most distressed: it should not be applicable to the general purposes of manœuvre. The rate of pace of the 'charge' should not exceed the full speed of the slowest horses, as it is from the uniform

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* This description of expense magazine may be constructed in masonry, and thus become permanent, although only adapted for a temporary supply.—*Editors.*

† By Lieut. and Adjt. Haviland, 2nd or Queen's Dragoon Guards.

velocity of the attacking body that its greatest effect is to be obtained. At the instant of the concussion the horse (although in hand) should be pressed forward.

There are three different modes of attack; viz. the Attack in Line—in Echellon—and in Column.

1st. The 'attack in line' is the form of attack against cavalry: its movement must be progressively quick; it must 'walk,' 'trot,' 'gallop,' and 'charge:' the latter must take place at a distance of 50 or 60 yards from the enemy; and as *support* is necessary to complete the success, or cover the failure, it should be formed as follows:

The support before the line advances to attack should be in two close columns in the rear of the flanks of the attacking line; and on the line advancing, it should advance in open column of troops from the leading squadrons: in the event of a successful attack, the open columns continue to advance and wheel in upon the flanks and rear of the enemy. If the attack fails, the columns are in position to cover the retreating line, and can frustrate any attempt to outflank.

2nd. The 'attack in echellon' is the best method of attacking batteries, and the easiest way of gaining a flank;—it also hides your intention from the enemy. The whole not being engaged (at the same moment), the rear echellons serve as a reserve, and deter an attack on the leading echellons, from the danger the enemy would be in of being taken in flank by the echellons that have not entered the line of attack.

3rd. The 'attack in column' is against infantry,—the most difficult and dangerous of cavalry operations: it should be made by squadrons in succession, and not attempted against squares of infantry until the fire of artillery has thrown the enemy into disorder.

A column of squadrons attacking squares should retire by *three's* from the outward flanks, the moment after the charge is made, so as to clear the front of the next charging squadron, and not to impede the impetuosity of its attack: the retiring squadrons should form in the rear of the *reserve*, and *never* upon the support, which would be thrown into confusion by a body in disorder falling back upon it.

Formations for attack should be in three distinct bodies; viz. for the *attack*, the *support*, and the *reserve*.

1st. The first body should be formed in line, and should be about one-third of the whole strength.

2nd. The 'support' may be in open column, in rear of the flanks of the first; or in line.

3rd. The 'reserve' should be either in close column of squadrons, or in double open column of troops (regimentally).

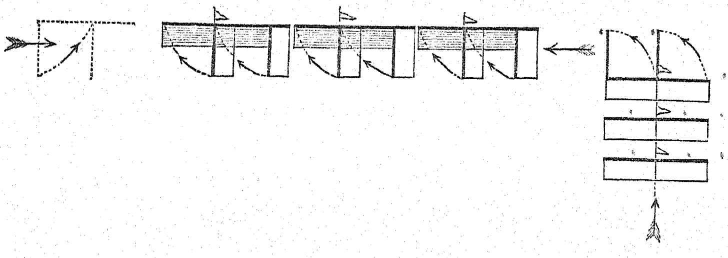
With respect to the manœuvres of a regiment of cavalry, they are so well defined in the '*Regulations for the Instruction, Formation, and Movements of Cavalry, dated Horse Guards, 1st January*, 1844,' that nothing more can be desired, except some orders relative to Manœuvres in Brigade, of which nothing has as yet been promulgated. The following movements have been found necessary and useful by the brigade of cavalry stationed this summer (1846) in Dublin.

1st. The cavalry in two columns of squadrons at quarter distance, on each flank of the infantry, (the infantry being in contiguous columns of regiments.) The right column of cavalry being left in front, and the left column right in front, is ordered to form line in front of the infantry (to mask its deployment); both columns will advance perpendicularly to their front, and then take ground in open column of troops inwards from the leading squadron (of each column) in succession, and, when the leading troops arrive within wheeling distance, 'wheel into line.'

See diagram of the right column, marked No. 1.

Part of Left Column.

Fig. 1.



NOTE.—REGIMENTAL COMMANDS FOR THE MOVEMENT.

Commanding Officer—{Take ground in ~~open~~ column of troops, to the left in succession from the 3rd (the leading) squadron.

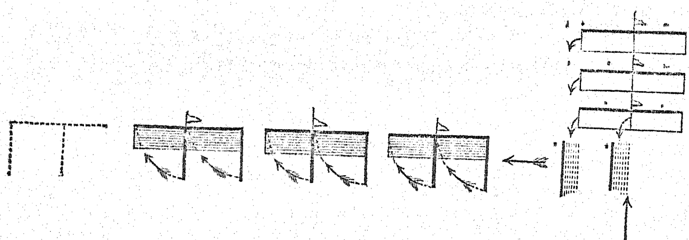
Leader of 3rd Squadron—Troops left wheel.

Leaders of remaining Squadrons—Advance, and Troops left wheel, when their squadrons arrive at the ground the leading squadron marched from, and follow in open column.

2nd Ex.—The cavalry in two columns of squadrons on the flanks of the infantry, as before, with this difference: the right column, *right* in front, and the left column, *left* in front; both columns advance, and then take ground in open column of troops inwards, from the *rear* squadron of each column in succession, and wheel into line when the heads of each column arrive at proper distance.

(The right column taking ground from its rear squadron.)

Fig. 2.



NOTE.—REGIMENTAL COMMANDS FOR THE MOVEMENT.

Commanding Officer—{By three's take ground to the left in ~~open~~ column of troops in succession from the 3rd (the rear) squadron.

Leader of 3rd Squadron—{Three's left, Leading three's (heads of troops) left wheel—Halt—Front—Forward, (followed in the same manner by the other squadrons in succession.)

3rd Ex.—The cavalry being in line in front of the infantry, is ordered to retire in open column of troops, and form close column in the rear of the flanks of the infantry.

The cavalry will retire from both flanks, and when the head of each open column has passed the infantry line by about 50 yards, they would receive the order to 'Form close column to the rear on the leading troop.'

Fig. 3.

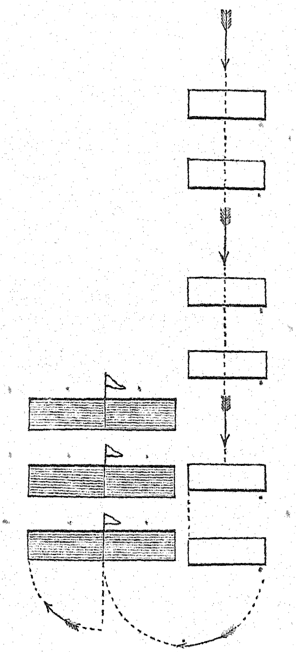
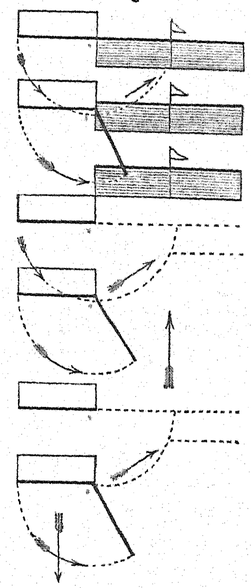


Fig. 4.



The Regimental commands to execute the manœuvre would be,—

Commanding Officer—Right about—Form close column.

Squadron Leaders—(Repeat the command).

Right Troop Leader of the 1st Squadron— { Right troop, right about wheel—Forward —(the depth of the column)—Halt.

Left Troop Leader of the 1st Squadron— { Right wheel, (when at the rear rank of the preceding troop) — Forward — (pass along the rear) Right wheel—Halt—Dress up.

The other Troop Leaders—The same in succession. The column would then stand right in front.

Ex. 4.—But if the right column (retiring right in front) is ordered to form the close column to the rear *left* in front, it must be done in the following manner on the rear troop. *Vide* diagram No. 4.

The right column retiring, and forming close column to the rear, *left* in front.

REGIMENTAL COMMANDS.

Commanding Officer— { Form close column to the rear on the rear troop.

Squadron Leader—(Repeat the command).

Left Troop Leaders—Left troop, left about wheel.

The Leader of the Rear Troop—**Halt—Dress.**

The other left Troop Leaders, (after wheeling about)—**Forward.**

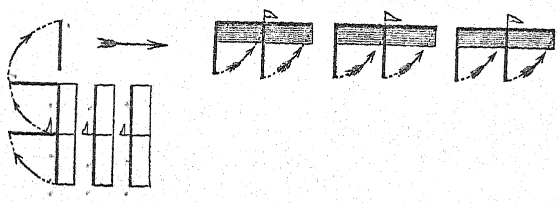
Right Troop Leaders— { **Three-quarters left about wheel—Forward —Trot—Left.Forward**—and on joining the left troop, **Walk**—until they close to the front—then the

Squadron Leaders—**Halt.**

Ex. 5.—The right column of cavalry is ordered to take up a new position to the right, but to the *rear* of the infantry.

The close column standing right in front will retire in open column right in front.

Fig. 5.



REGIMENTAL COMMANDS FOR THE MOVEMENT NO. 5.

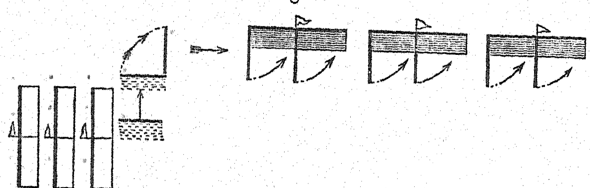
Commanding Officer—**Retire in ~~open~~ column from the right.**

Leader of 1st Squadron—**Troops right wheel—Forward.**

And when the right troop has passed the reverse flank by one horse's length, its Leader will give the word **Right wheel—Forward.** The left troop follows the right, and the remaining squadrons wheel *off their ground* in succession, and follow the 1st squadron in open column of troops;—and when the open column arrives at the position ordered to be taken up, it will wheel (left) into line.

Ex. 6.—If the right column of cavalry should stand left in front, when ordered to take up a new position to the right, but in rear of the infantry, it can easily be executed (without countermarching) by three's taking ground in open column to the right in succession from the rear squadron, and changing direction to the right.*

Fig. 6.



REGIMENTAL COMMANDS.

Commanding Officer— { **Retire in ~~open~~ column, right in front, in succession from the rear (1st) squadron.**

Squadron Leader of the rear (1st) Squadron— { **Three's right—Leading three's** (heads of troops) **right wheel—Halt—Front—Forward.**

* In detailing the foregoing manœuvres, the diagrams and commands are laid down for the right wing of the brigade: of course it will be necessary to substitute *left* for *right*, and *right* for *left*, for the *left* wing.—F. H.

As soon as the word **Forward** is given by the Squadron Leader, the Leader of the right troop will give the word **Right wheel—Forward.** The other squadrons will proceed in the same manner in succession, which will bring the whole into open column right in front;—and when the column arrives at the position ordered to be taken up, it will 'Wheel into line.'*

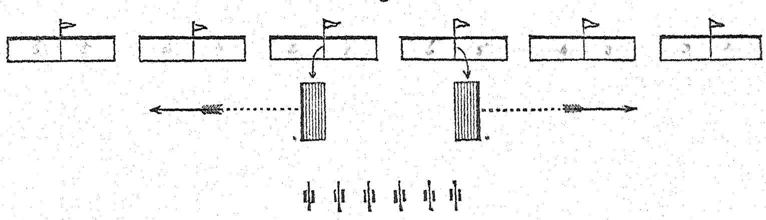
In the 'Cavalry Drill-Book,' page 192, Movement No. XI. from line, the troops wheel about to execute the movement; but supposing a line of cavalry masking artillery was ordered to retire in column of troops from the centre in succession by the rear, to quickly clear the front of the guns, it could not be done by the troops wheeling about; but it can be by the following method (which would allow the artillery to come into action): viz. 'By three's open column of troops from the centre in succession by the rear.'

Commands.

Left Troop Leader of the right wing— { **Left troop—Three's right—Leading three's right wheel—Halt—Front—Forward.**

Right Troop Leader of the left wing— { **Right troop—Three's left—Leading three's left wheel—Halt—Front—Forward.**

Fig. 7.



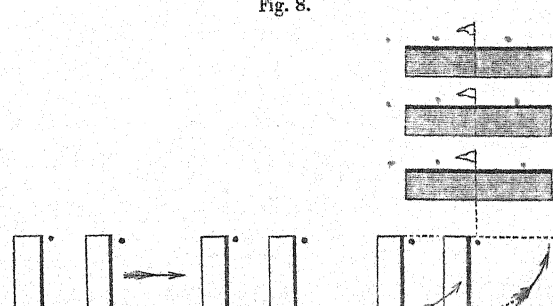
Each troop will follow in succession in the same manner; the right wing will be a column left in front, and the left wing a column right in front: then, by changing the direction of the heads of the column, the cavalry would be en route to get under cover of the infantry, or be in position to re-form line to any front.

The following manœuvres are useful as Regimental Movements, but not laid down in the '*Instructions for the Cavalry.*'

1st. A regiment being en route in open column of troops right in front, is required to form a close column to its pivot flank.

To the pivot flank form close column.

Fig. 8.

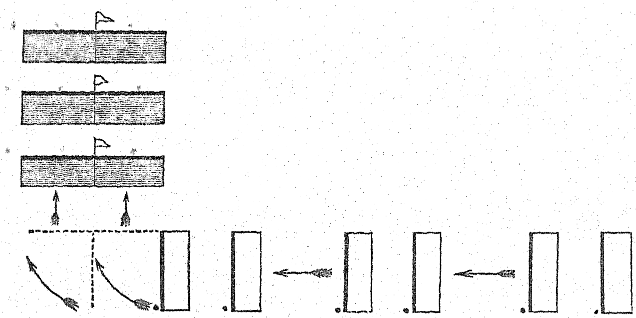


* See previous Note.

Leader of the 1st Squadron—	Left wheel into line—Forward (move up the depth of the column)—Halt.
Leaders of the other Squadrons, as they arrive upon the ground upon which the 1st wheeled into line—	Left wheel into line—Forward, (and when at proper distance from the preceding squadron)—Halt—Dress.

To the reverse flank form close column.

Fig. 9.



Leader of the Right Troop of the 1st Squadron—	Right wheel — Forward (the depth of the column)—Halt—Dress.
Leader of the Left Troop of the 1st Squadron—	Right wheel (after passing along the rear of the right troop)—Forward—and—Halt, when on a line with the right troop.

The other Troop Leaders—The same in succession.

MANŒUVRING HORSE ARTILLERY.*

The following extracts form part of a 'Code of Instructions for the Exercise and Movements of the Royal Horse Artillery,' drawn up in obedience to the directions of Lieutenant-General the Right Honourable Sir James Kempt, Master-General of H. Majesty's Ordnance.

The principles which govern the application of Horse Artillery, as well as the encampment, the embarkation and disembarkation of troops, &c., &c., being the same as with Field Artillery in general, are not repeated in the following code, as they may be found on reference to the '*Instructions and Regulations for Field Battery Exercise*,'† of which each Officer in the regiment of Artillery is required to have a copy in his possession.

GENERAL PRINCIPLES FOR THE MOVEMENTS OF HORSE ARTILLERY.

PRELIMINARY OBSERVATIONS.

The same general principles regulate the Manœuvres of Infantry, Cavalry, and Artillery: as the infantry is, however, the main body of an army, it must govern the movements of the other Services, and therefore this exercise has been prepared in conformity thereto.

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* From 'Regulations for the Exercise and Movements of the Royal Horse Artillery.'

† See Article 'Evolutions of Artillery,' in 1st volume of 'Aide-Mémoire.'

The plan of the '*Regulations for the Field Exercises and Evolutions of the Army*,' and of the '*Cavalry Regulations*,' has been followed, and the general principles, movements, and words of command, have been adopted as far as the difference between the Services rendered it expedient.

Horse artillery should, as frequently as possible, be exercised with cavalry and infantry, that they may acquire the habit of manœuvring in a confined space, without embarrassing the troops, who move as if no artillery were attached to them. Several of the manœuvres in the exercise have been introduced with this view.

A troop of horse artillery can perform nearly every manœuvre of a brigade of cavalry or battalion of infantry. Many of the movements are more a matter of show than of real utility. The evolutions of several troops acting together are on the same principles as those of one troop.

Whenever several troops can be assembled, the opportunity of exercising them together should never be neglected; eight or ten days' drill will be attended with the greatest benefit to both officers and men; will enlarge their ideas, and shew them how easily considerable bodies of artillery can be moved: it will also accustom them to preserve their distances correctly, which is most essentially necessary, particularly when artillery is acting with other troops. This must at all times be strictly attended to.

The horse artillery, without being obliged to follow, step by step, all the manœuvres of the cavalry or infantry, proceeds to the execution of the orders it receives in the easiest and most expeditious manner. The proper employment of that particular arm, according to the situation of the ground, and the circumstances of the case, must ever be kept in view in all orders issued to it.

In cases of parade or review, it is absolutely necessary that the Commanding Officer should be made acquainted with the intended manœuvres, in order that his movements may have a proper effect.

It should be remembered that horse artillery cannot be wheeled about on its own ground when acting with other troops: sufficient ground should be allowed on each flank to enable the subdivisions to wheel outwards, if required.

Horse artillery can readily be moved from one part of the line to another, but for purposes of review it should never be brought up into its position till all the troops are posted; for it sometimes happens that after the ground is occupied, the whole are ordered to move a few yards, or even a few feet, to a flank; or to dress back. Neither of these occasions much trouble to the infantry or cavalry; but it must be evident that to move a line of carriages a few yards to a flank, the whole must go to the rear, and each carriage make a considerable circuit, in order to come up square into its place: backing the carriages will rarely answer for any distance, when for the purpose of correct dressing.

Although, strictly speaking, a troop of horse artillery has no right or left, but only acknowledges the front to which the guns and detachments are facing, yet, when a troop is reversed, the Commanding Officer, in ordering an advance or retreat from either flank, should make use of the word '*Present*' (*right* or *left*), which distinguishes it from the *proper*.

Should any difficulty of ground cause the natural order of the subdivisions to be inverted, their relative situations should be resumed at the earliest opportunity.

When the guns come into action at exercise, they should always direct their fire to a particular object, the distance of which should be named by the Commander, in order that the elevation may be regulated; or he will name the elevation.

In all manœuvres, as soon as the gun is limbered up, the detachment mounts and dresses on the subdivision of direction, on the word given by the Nos. 1.

FORMATION OF A TROOP.

A troop of horse artillery usually consists of six pieces of ordnance: the men required for the service of each piece are—

For light ordnance. Eight mounted men, of which two are non-commissioned officers.

For medium. Ten mounted men, of which two are ditto.

Heavier. Twelve mounted men, of which two are ditto; with an addition of two men to each piece, mounted on the limbers, and numbered 2 and 3.

The mounted men are numbered off as follows, viz.

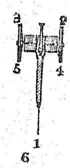
With light ordnance.
- Front rank 4. 12.* 5. 1.—Senior non-commissioned officer.
- Rear rank 7. 13.* 6. 11.*—Junior ditto and marker.

With medium ordnance.
- Front rank 4. 12.* 5. 10. 1.—Senior non-commissioned officer.
- Rear rank 7. 13.* 6. 14. 11.*—Junior ditto and marker.

With heavier ordnance.
- Front rank 4. 12.* 5. 15. 10.* 1.—Senior non-commissioned officer.
- Rear rank 7. 13.* 6. 16. 11.* 14.—Junior ditto and marker.

* This mark denotes horse holders.

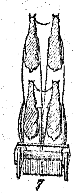
Each piece of ordnance is attended by an ammunition waggon, on the limber of which two men are mounted, numbered 8 and 9.



In this mode of telling off the men, they are numbered as much as possible in conformity with the field batteries, so that there may be a unity of principle with all field ordnance.

The non-commissioned officers and mounted men are called a detachment, which is placed in front, rear, or on a flank of their guns, according to circumstances.

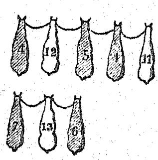
No. 2 sponges, 3 loads, 4 serves the vent, 5 fires, 1 commands, 7 is in rear of the limber, 6 stands five yards in rear of the left wheel, and serves 3 with ammunition from 7.



When the number of men attached to a gun is reduced, 5, 6, 7 can best be spared, the gun continuing in action without them, by 3 going to the rear for ammunition, and 1 doing the duty of 5 in addition to his own. In action, Nos. 11, 12, 13 continue mounted in charge of horses; No. 11 leads his officer's horse and that of No. 1 to the rear; No. 12 those of 4 and 5; and 13 those of 6 and 7.

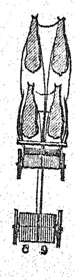
When a detachment is reduced to six men, they are numbered

4	12†	1	†12 and 11 being
7	11†	6	horse holders.



Although ten yards is the distance nominally allowed the limbers in action, in rear of their guns, yet it is to be observed, that when the nature of the ground is such as will in any degree cover them from the effect of the enemy's fire, a non-commissioned officer is perfectly justified in taking advantage of it, when the distance does not exceed a few yards either way.

In action, the whole are disposed of in the manner shewn in the annexed diagram.



With respect to ammunition waggons, no positive rules can be laid down as to their disposition in action, which, on service, must in a great measure depend on a variety of circumstances: when it is practicable, they should be under the charge of an Officer, whose duty it will be to conform to the movements of

the guns in such manner and at such distance as to enable him to supply them with ammunition before that which is in the limbers can be expended: the spare carriages should be under the charge of the Quarter-Master Serjeant.

FORMATION OF A TROOP FOR INSPECTION.

Each troop forms in line with its guns, &c., in rear of their respective detachments, and in order to enable the rear rank to rein back for inspection, the leading drivers to be six horses' lengths from the rear rank: the inspection is then made according to order.

Distance of ranks. The distance of ranks is taken from the head of the rear horse to the tail of the front.

Close order. Half the length of a horse.

Order. Four horses' lengths, unless otherwise ordered.

Distance of files. The distance of files is six inches from boot-top to boot-top. *Close files*—when the boot-tops touch without pressing.

Distance between guns. In line, the regular distance from gun to gun is, with four horses, 16 yards, and 3 yards additional for every additional pair of horses; consequently there will be the same distance between the right of detachments.

Distance of guns from their detachments.

In the rear.—Leading drivers one horse's length in rear of detachments, covering the centre.

Guns. *On a flank.*—A short horse's length from the flank of their detachments.

In front.—Detachments one horse's length in rear of their guns.

When a line breaks into column with detachments on a flank of their guns, it leaves an interval of two horses' lengths between the muzzle of each gun and the leading driver of the next.

OFFICERS, HOW POSTED.

2nd Captain. At open order, he should be on the right, and in line with the subalterns two horses' lengths;—at close order, and during manœuvre in line, between the two centre subdivisions, from which position he will be able to see the orders of the Commanding Officer properly executed, and be more ready to get to either flank for the purpose of dressing points. In column, he should be two horses' lengths from the centre on the reverse flank.

Subaltern Officers. The Commanding Officer places the Officers, one subaltern on the right of the troop, one on the left, and one on the right of the third subdivision (or of the fourth, if he means to name it the subdivision of direction).

Serjt.-Major. The Serjeant-Majors are to be in rear of the right gun of their respective troops two horses' lengths; when the waggons are attached, two horses' lengths in rear of the right waggon; in column, right in front, two horses' lengths on its reverse flank, dressing by the head of the column. When the left leads, and the Quarter-Master Serjeants are detached, they are to shift there, and keep on its reverse flank.

In changes of position in column they may be usefully employed in sometimes conducting pivots, and when a line is forming, in dressing or giving true points to their respective troops, in the given direction. It is their duty to see the limbers are properly disposed of when the guns are in action.

Quarter-Master Serjeant. The Quarter-Master Serjeants to be in the rear of the left gun of their respective troops (on the left) two horses' lengths; in column, on its reverse flank: they also assist in taking up points, &c., as well as the Serjeant-Major.

Trumpeters. The trumpeters on the right of the line, the left file two horses' lengths from its

flank: when the movements are about to commence, they will join the respective troops, and be disposed of along the line, as the Commanding Officer may direct.

Artificers.

The artificers in the rear of the whole, two horses' lengths behind the centre of their respective troops, and dressing to the same points as the line: they are considered detached in all situations of manœuvre.

A TROOP, HOW TOLD OFF.

The Commanding Officer, after numbering off the troop from the right by detachments, guns, and waggons, will tell it off into subdivisions, divisions, and half troops.

Throughout the service of artillery, six guns are generally termed a troop: for this reason it is the custom to tell horse artillery off as troops; two guns, with their detachments, constitute a division; one, a subdivision.

The waggons, although numbered with their guns, are not to be considered as part of the subdivision; but while they remain with them, they are to conform to every movement.

It may be sometimes necessary, in the march of columns, even to diminish the fronts of detachments; each detachment is therefore told off in *two's*.

Formation of several troops.

When two or more troops are to act together, they are formed in line, and told off in the same manner as for a single troop; the Captains are one horse's length in front of the centre of their respective commands, which commands will be allotted to them by the Commanding Officer; and when the reports are collected and made to him, he will number them by troops and half troops from the right.

WHEELING.

Wheeling is a most essential operation, necessary in many changes of position, and in the formation of column and line.

When a troop is to wheel, a caution is given for that purpose, and to which hand. At the word '*March,*' the front rank dresses by the Officer on the wheeling flank, who fixes his eyes and makes his circle on the standing flank man, and takes care that he does not exceed a moderate gallop.

The leader must take care to time his words '*Halt—Dress*' before the wheel is completed, otherwise an over-wheel and reining back will be the consequence. The whole halt, and dress by the standing flank.

The troop breaks into column of any of the parts into which it is told off, by each of those parts wheeling up the quarter circle.

If the body is in motion, the wheels begin at the word '*Wheel;*' if halted, they are to begin at the word '*March.*'

In all wheelings, the conductors of the subdivisions look to the Officer or the non-commissioned officer on the wheeling hand, and their subdivisions look to, and dress by them: at the words '*Halt—Dress,*' the whole are dressed to the standing flank, and remain so till a new direction is given, which will be—

$$\text{'}\textit{Eyes}\begin{Bmatrix}\textit{right'}\\ \text{or '}\textit{left'}\end{Bmatrix}\text{to the pivot flank when necessary.}$$

Distances in column are preserved from front rank to front rank.

When the line is to be formed by the wheeling up of its divisions, there must be no false intervals—the pivot man of the wheel turns his horse on his fore feet, keeps his ground, and comes gradually round with the rank.

Wheels of divisions of the line are made on a halted or a moveable pivot; they are made from line into column, or from column into line, and also by the column of manœuvre or march, when moving on a considerable front, and when the wheel by which its direction is to be changed approaches to or exceeds the quarter circle.

When on a moveable pivot, they are generally used, and ordered when the front of the column is small and its path winding and changeable. Although after the completion of the wheel in column or on a halted pivot, the pause made gives time, in large fronts, for exact dressing before the march is resumed, yet in small ones, where that pause is short, there is no time for such; attention to the preservation of the true distance being the material object. Whenever the wheel made is less than the quarter circle, the pause after the wheel will be considerable: should the wheel be greater than the quarter circle, it must be accelerated, otherwise more than one division will be arrived, and arrested at the wheeling point. Whatever is the front of the column, the words '*Halt—Dress*' are to be given just before the wheel is completed.

When wheels, or changes of direction of bodies in column, are made on a moveable pivot, both flanks are kept in motion, the pivot one describing part of a circle, and the reverse flank, and intermediate men, by a compound of inclining and wheeling, conforming to the pivot movements.

When the change is to be made to the pivot hand (the whole being in motion), the leader of the head of the column, when at the distance of twenty or thirty yards from the point of intersection of the old and new direction, will give the word—

'*Right*' or '*left*' } '*shoulders forward;*'

which is a caution for each man to give a small turn of his horse towards the pivot hand; and the leader himself, carefully preserving the rate of march, without the least alteration of pace, will, in his own person, begin to circle into the new direction, so as to enter it 20 or 30 yards from the point of intersection. When this is effected, (the rest of his division continuing to dress by him,) he will give the word '*Forward*,' and pursue the straight line. The leader of the second, and every other division, when he arrives at the ground on which the first began to wheel, will in the same manner follow his exact tract, always preserving his proper distance from him.

When the change is to be made to the reverse flank, the pivot leader having arrived, as before, at the spot, when he gives his word—

'*Right*' or '*left*' } '*shoulders forward*,'

for each man to give a small turn of his horse from the pivot hand, will begin, in his own person, to circle gradually into the new direction, so as to enter it 20 or 30 yards from the point of intersection of the two lines, when he will give the word '*Forward*.' During the change of either hand, the whole continue to look to the pivot flank, which never alters its former rate of march: in the one case the reverse flank is obliged to slacken, and in the other to quicken its movement. In this manner, without the constraint of formal wheels, a column, when not confined on its flanks, may be conducted in all kinds of winding and changeable directions; for if the changes be made gradual and circling, and pivot leaders preserve their proper path at the same uniform equal pace, the true distance of divisions will be preserved, which is the great regulating consideration on this occasion, and to which every other must give way.

Reversing. The command to reverse means, that each gun and detachment is to go about on its own ground, the one quite independently of the other; it is therefore very rarely given, but when the detachments are in front or rear of their guns, the word '*Right*' or '*Left*,' prefixed to '*Reverse*,' denotes to which hand.

In putting subdivisions about by sound of bugle, the following rules are to be observed:

With detachments either in front or rear, it means they are to reverse to their left;

with detachments on the left, to wheel to the right about; and with detachments on the right, to wheel to the left about.

MARCHING IN LINE.

The line being supposed halted, and dressed for the purpose of advancing, the leader of the directing subdivisions instantly endeavours to remark two or more objects in his front which are exactly perpendicular to the direction of the line: on the word '*March,*' he is to move on those objects, taking particular care as he approaches them to take up others in the prolongation of the direction in which the line is moving.

It must be the particular care of conductors of subdivisions, during the advance, to retain their proper distances from each other.

Inclining.

Inclining is a movement by which a line or any part of it is carried on in a parallel direction, at the same time that it is gaining ground to a flank; it is equivalent to the oblique march. '*Right*' or '*Left—incline.*' At the word '*Incline,*' each man turns his horse on his fore feet, to the hand to which he is to incline, and the whole look to that hand. At no time during the incline ought the former front of the line to be in the least degree altered; that whenever the word '*Forward*' is given, the line (by each man at the same instant turning his horse) may be in a direction perfectly parallel to the former front, and ready to dress, or move on by either flank or centre. It has been ascertained that the greatest angle at which cavalry can incline is 34°, but artillery (in consequence of the intervals between subdivisions) can, if necessary, incline to a much greater angle.

PACES.

The walk, trot, and gallop, are the three paces; and of each of these there are different degrees of quickness: but it is essential to the perfect movement of the troops, that every horse shall move at the pace ordered: different paces ought not to be suffered in a body moving at the same rate. The Cavalry Regulations (Sec. 15, 16,) must be strictly adhered to.

All alterations of pace must be made by each separate body composing a line or column as nearly together as possible. Though in slow movements of the line or column, or on a march, the walk is the common pace, yet, in general, all changes of position should be made at the trot or the gallop, according to circumstances, beginning and ending gently, to avoid confusion in forming: the intermediate time of such movements may be conducted with rapidity, and much depends on the eye of the Officer, and in well-timing the words of command.

COMMANDS.

All commands must be given by Officers, firm, loud, and explicit; every Officer must therefore be accustomed to give such commands, even to the smallest bodies, in the full extent of his voice: by such bodies he must not only be heard, but by the leaders of others, who are dependent on his motions.

Nature of commands.

Commands of caution being such as are preparatory to a movement, should be sufficiently full and explanatory. Commands of execution should be short, and avoiding unessential words.

Commands by respective leaders.

The Officer commanding gives and repeats all general commands, which are also quickly repeated by all the Officers and by the senior non-commissioned officers of such divisions as have no Officer: it is only when troops are broke into parts, that there is no Officer attached to the subdivision, that the Nos. 1 give commands, and those are chiefly executory, as '*Halt—Dress,*' *&c.:* also the several words necessary for

the wheels made in column of march by subdivisions;—the several words necessary when the subdivisions come up successively from column into line, and in general whenever the subdivisions are moving as distinct though dependent bodies;—but the wheeling from general column into line, or from line into general column, is made at the word '*March*,' repeated by the Officers and non-commissioned officers commanding divisions only. The whole column or line is also put in motion according to the same rule; but all general words of command given by the Commanding Officer to the whole when in motion, should be instantly repeated, not only by the Officers and non-commissioned officers commanding divisions, but also by the non-commissioned officers commanding such subdivisions as have no Officers attached to them.

It is impossible to ascertain the words of command to be given in all cases; when such are not pointed out, they must depend on circumstances: if they are clear and expressive of what is to be done, they cannot be too short.

Quick repetition of command.

After the Commander has announced the orders, &c., particularly the words of execution, as '*March—Halt*,' *&c.*, the repetition of them by every other individual concerned, must not be strictly successive, but as much as possible at the same instant, to insure that precision of movement which is so indispensable; and the larger the body, the more essentially does this circumstance operate.

MOVEMENTS.

Movements ought to be divided into distinct parts, and each executed by separate and explanatory words of command.

Alterations of position in considerable bodies must begin from a previous halt, however short, except giving a new direction to the heads of columns, or increasing or diminishing their front, which may be done while in motion. As the principle of moving, forming and dressing, upon given and determinate points, is just,—quick changes of position of a considerable body, formed in line, attempted while on the move, and not proceeding from a previous halt (however short), will be false and defective; the effects of which, although not apparent in a single troop, would be very obvious in a line or column of any extent: a pause between any change of situation, so essentially necessary to movements of great bodies, should seldom be omitted in those of small ones.

Squareness of dressing, the exact perpendiculars of march, and the correct relative position of the whole, are thereby ascertained.

Such alterations of position, made from the halt, may, when necessary, succeed each other instantly; no time need be taken up in scrupulous dressing, that every one may be immediately apprised of the movement which is to follow.

In the movements of a single troop, and in the taking up a new position, it may not seem material whether a flank of it is placed a few yards to the one hand or the other, or whether the line formed on is exactly directed to any certain point; but when a troop makes a part of a more considerable body, if its formations are not correct, it will create general confusion, and give false directions and distances to those whose situations may be determined by it.

The necessity of every single troop being accustomed to make its changes of position and formations on determined points is therefore obvious.

Every leader of a body, moving on any front whatever, who means to conduct it in a straight line, must march upon two points, which cover each other: if such points are not ascertained for him, he must instantly determine them for himself; and if no strong and marked objects present themselves in the direction, he can never fail, by casting his eyes along the ground, to find such small ones as will answer his purpose; and these he renews from time to time, as he approaches them. To march

straight on one object only, with certainty, and without wavering, is not to be depended on.

MARKERS, IN FORMING LINE.

When a column is wheeled up into line, the front rank is dressed on the markers' horses' heads, so that the men of the front rank will of course be half a horse's length from the line of the horses' heads of the marking persons. The same rule is to be observed in all formations of line, as well as in the connecting of a line, when it is necessary to throw out markers for that purpose. With the guns in rear or on a flank, the Nos. 1 march on the markers; and with guns in front, the leading drivers are marched on them.

The markers for these formations (except for action) are not to quit their ground till all the necessary dressing is accomplished, and they are directed so to do by '*Eyes front*,' from the Commanding Officer.

MOVEMENT FROM A FLANK OR FLANKS.

If a line is ordered to move off from any part of it in a column or columns, the following rules will serve as an explanation for all cases that can occur. If a troop in line with detachments on the left of their guns, is ordered to advance from the right in a column of divisions, the Officers, having repeated the words of command, will immediately place themselves on what is to become the pivot flank of their respective divisions, by shifting along the front: on the word '*March*,' the whole move off at the pace ordered, the right division straight on; the remainder wheel to the right by subdivisions, and move on without any pause; and as soon as the second division covers the first, that is, when the third subdivision covers the first, and the fourth covers the second, it is wheeled to the left by subdivisions: the other divisions will be wheeled up in the same manner as they cover in the new direction.

In retiring from the right flank, on the word '*March*,' the two right subdivisions wheel to the right about, and then move on; the other divisions follow, as already directed.

In retiring from the left, the two subdivisions on the left of the line wheel to the left about. In some cases, however, the above-mentioned method of retiring from a flank may be considered objectionable; for instance, if, after having retired from the right in this manner in a column of divisions, and that it becomes necessary to wheel into line to the left, the consequence would be, that after having wheeled into line, the order in which the divisions were originally told off would be inverted: the second subdivision would be on the right of the first; the fourth on the right of the third; and the sixth on the right of the fifth: therefore, when the next formation is foreseen, and that it is such as will affect the original order of the subdivisions, according to the rule already explained, the Commanding Officer, when he wishes to retire from the right flank by divisions, will change the front of the right division by subdivisions wheeling inwards about; the remaining divisions wheel to the right, and follow the first division: the same principle is applicable to retiring from the left flank.

FORMATION OF LINE FROM COLUMNS.

It is a general rule, in all formations of line from open column, that the part of the column next to that which is to be formed on (in order to enable it to form perfectly square) shall make two square movements; the remainder, to avoid going over unnecessary ground, need only throw shoulders forward. From close column the whole must necessarily make two square movements.

These rules apply equally with columns of every front.

BREAKING AND FORMING.

A troop formed in line occupies 100 yards nearly, when it moves from a flank in a column of subdivisions (without ammunition waggons): with the detachments in front or rear of their guns, it occupies about a third more than it did in line; but if it moves from a flank in a column of subdivisions, with detachments on a flank of their guns, by divisions, or in a column of a larger front, the distance between the front and rear pivot officers is less than the troop occupied in line, by the front of the column, whatever it is.

Leaders in column.

When a line is broke into parts for the purpose of movement, each of these parts has a leader, who, in column if an Officer, is always to be on the pivot flank: these Officers cover each other in the given direction in which the column is to move; they are not to be covered by any one, and are answerable for preserving true distances. Should there not be a sufficient number of Officers for this purpose, their places are to remain vacant, and not to be occupied by the flank files, for such flank files are invariably to cover each other.

Commands given in breaking into column.

When from the halt, a line, by wheels to a flank, breaks into open column, the words of command are—'*Half troops, divisions,* or *subdivisions, to the right* or *left wheel—march.*' When the wheel is completed, the respective commands of half troops, divisions, &c., give the words '*Halt—Dress*' (by the standing flank), and then '*Eyes right*' or '*left*' (by the pivot flank); after which the whole is put in motion by the word '*March,*' dressing, as already directed, for the column.

Pivot leaders in column of half troops.

In wheeling to a flank by half troops, if to the right, the Officer attached to the centre division shifts to the left of the third subdivision, in order to conduct the pivot of the leading half troop; and the Officer who was on the left, wheels up, and remains on the pivot flank of that half troop; the Officer who was on the right continues there: if to the left, the Officer attached to the centre will be on the right of the fourth subdivision, the left Officer continuing where he was; and the Officer on the right continues there to conduct that half troop.

Pivot leaders in column of divisions.

In wheeling to a flank by divisions, if to the right, the Officer on the right shifts to the left of his division; the Officer next the centre to the left of his division, and the Officer on the left of the troop remains on the left of his division. If the divisions are to wheel to the left, the Officers who are not already there shift to the right of their divisions.

Pivot leaders in column of subdivisions.

In wheeling by subdivisions, if to the right, the Officers are to be on the left of the first, third, and sixth subdivisions; if to the left, on the right of the first, fourth, and sixth subdivisions.

NECESSARY EXTENT OF A COLUMN OF MARCH.

It is a general rule, seldom to be deviated from (when it can be avoided), that a troop when moving in a column ought not to occupy more ground than in line. In all wheels of a column to change its direction, with a larger front than subdivisions, on a fixed flank, the outward Officer, or non-commissioned officer (when there is no Officer with the outward subdivisions), directs the wheels, the quickness of which must be at least double the rate of marching, or the wheeling point would not be cleared in time for each successive division. In changes made on a moveable flank, the outward Officer or non-commissioned officer also directs.

Halt of the line or column.

The whole line or column should always be so correctly dressed, that when the word '*Halt*' is given, the whole shall halt together; but should at any time the difficulties of ground, or any other cause, have opened out the column, or thrown subdivisions out of the line, in such case the halt of such must be successive, that is, they will not be halted till they regain their proper situation.

Close column. The general object of a considerable close column, is to form the line to the front in the quickest manner possible, to conceal numbers from the knowledge of the enemy, and to extend into whatever direction the circumstances of the moment may require, which, till it is nearly accomplished, cannot be obvious to them.

A close column of cavalry has generally a front of half squadrons, and when it is meant to deploy into line, it very frequently doubles its front into squadrons.

A close column of horse artillery will be composed of divisions, or of a greater front, according to circumstances. In close column it will be found sufficient to have distances of two horses' lengths from the rear of subdivisions to the front of covering subdivisions.

The changes of direction in a close column must always be made on a moveable pivot, to enable its rear gradually to comply.

In deploying into line, the whole do so by making two square movements, viz. by wheeling twice. Cavalry deployments from close column are generally made at the head of the column.

MARCH IN LINE.

It requires the greatest attention to march well in line: the subdivisions dress by their respective leaders, who must be particularly careful in preserving their distances, and guard against closing in on each other.

When any part of a line is interrupted by an obstacle, each subdivision, on approaching it, will throw shoulders forward, or wheel, if necessary, and continue its march in rear of the nearest subdivision which has not been so interrupted.

In proportion as the subdivisions pass such obstacles, and that the ground permits them to form in line again, they will move up into their proper places, (where a void space has been preserved for them,) by throwing shoulders forward.

INCREASING OR DIMINISHING THE FRONT OF A COLUMN OF MARCH.

A column should not occupy a greater extent of ground than what it takes to stand on in line: it therefore follows, that whatever changes are necessary, the column ought not to be lengthened out while it can be avoided. The front of a column may be increased or diminished, either in motion or when halted; in motion it is performed either successively as each part arrives at the spot where the head of the column performed the operation, or by all at the same moment: in both cases, the Commanding Officer, when he intends reducing or increasing the front, gives the caution, and the leaders the necessary commands, taking care that the regulating divisions, subdivisions, &c., never alter the pace at which the column was marching, but proceed as if they were totally unconnected with what the others were performing; the proper pivot is, however, always to be preserved, unless circumstances require that it should for the moment be dispensed with.

While the detachments are on a flank, a column of subdivisions does not cause any lengthening out: if it is still necessary to decrease the front of the column, the detachments may be ordered in front or rear of their guns: if more, by throwing out a file, one in front, the other in rear, it may be necessary to decrease it sometimes still further, (when there is not room for three files abreast,) by doubling the left files behind the right, the word of command for which is, '*Left two's, right double.*' Filing from a flank answers the same purpose.

If a column of subdivisions right in front, is in motion, and the Commanding Officer wishes to increase the front of the column in succession, the Officer at the head of the column, halting in his own person, orders to the reverse flank all the subdivisions that are in front of the subdivision which will become the pivot one; the sub-

divisions so sent to the reverse flank taking their intervals, dressing, and rate of march, from the pivot gun.

COUNTERMARCH.

In the movements of cavalry, the countermarch of lines and columns is sometimes necessary; in those of the horse artillery the former is seldom or ever required; but the countermarch of the column is perfectly applicable, when it is desirable it shall face in the contrary direction, and preserve its line of pivots.

In the countermarch of a column right in front, the Commanding Officer will give the caution to countermarch to the right, on which the coverers of subdivisions will place themselves on the pivot flanks, in a line with the muzzle of the gun, but facing to the rear: on the word '*March*,' the whole move off together; the detachments, after having advanced five horses' lengths, are halted by their respective Officers or non-commissioned officers, the guns continue moving on, and when they are sufficiently distant from their markers to allow them to be formed quite square in the opposite direction, both guns and detachments are wheeled to the right about; the latter on their centre; both receiving the word '*Halt—Dress*,' from their respective commanders, or their coverers: the column will thus change its front and flanks.

Wheeling the detachments about answers the same purpose as filing, and is attended with less risk in the operation.

In the countermarch, the detachments and guns are invariably wheeled severally about, towards the flank which is not the pivot one.

ECHELLON.

The echellon position, and movements, are applicable in many situations, and they are particularly adapted to resist attacks in front, and flank or flanks.

The oblique change in echellon is produced by the wheel less than the quarter circle of subdivisions; it is therefore practised when it is wished to move to the front or rear, and at the same time to gain ground to a flank.

The direct echellon is produced by the perpendicular and successive march of subdivisions to front or rear.

CHEQUERED RETREAT OF THE LINE.

The movements of a corps of cavalry retreating will be generally more or less accomplished by chequered movements.

Cavalry frequently retire by alternate squadrons, or half squadrons; no determinate rule can, however, be laid down for the movements of horse artillery attached to cavalry, in such cases, as they must very much depend on the nature of the country to be defended.

With cavalry, the line is told off by alternate right and left squadrons and half squadrons; and of two that are contiguous, one for the direction of each line is announced. When it is the intention to retire, the right squadrons or half squadrons are ordered to stand fast; the left go about by three's; the retiring part marches a certain distance, and when ordered, halts and fronts: this serves as a signal for the advance part of the line to begin its retreat in the same manner, each going through its proper interval, and when ordered, halts and fronts: the alternate retreat is thus continued at the rate ordered, while found necessary.

As a general rule, (subject to exceptions,) the artillery will be on the flanks of regiments or brigades, according to circumstances, and told off right and left subdivisions, divisions, or half troops, in proportion to the number of guns; the right retiring with the right squadrons or half squadrons, the left guns with the left, each unlimbering when halted, and firing when it can be done with effect.

In many situations, especially when a retreat is conducted with order, and slowly, it will be found that the retiring with the prolong has many advantages; by that method a constant fire may be kept up, and the frequent limbering and unlimbering (by which much time is lost) is avoided.

In a third method, where ground and other circumstances will admit, the whole of the guns may remain with the rear squadron, which will give confidence to the cavalry, and check the enemy in proportion.

NOTE ON HORSE ARTILLERY MOVEMENTS.

The movements of this superior branch of the Service in the field has been detailed more at length for the use of Cavalry and Staff Officers, the movements being more complicated, by the large proportion of horses and the rapidity with which the changes of position are made. This arm fulfils all the advantages of foot artillery batteries, sometimes in a superior degree, as well as the power of accompanying cavalry in equal time and on any ground.—*Editors.*

MANTLETS * are musket-proof coverings used to close the interior openings of embrasures in casemates or parapets, to protect the head of approaches carried on by sap, and occasionally to afford additional protection in rear of the last placed gabions: they may also be employed to cover the approach of men against a stockade, gate, or barrier, for the purpose of placing a charge of powder to effect their demolition.

From experiments made by Capt. M'Kerlie, R. E., at Chatham, it appears that the following materials afford musket-proof covering:

	Weight per foot super.
9-inch Baltic fir	28 lbs.
6-inch ditto with $\frac{1}{8}$-inch iron plate in rear	25
$3\frac{1}{2}$-inch sound oak	$16\frac{1}{2}$
$2\frac{1}{2}$-inch oak with $\frac{1}{8}$-inch iron plate in rear	$17\frac{1}{2}$
One thickness of 1-inch and one of 2-inch oak, placed equidistant $\frac{3}{4}$ inch from a $\frac{1}{12}$-inch iron plate between	$17\frac{1}{2}$
$\frac{3}{8}$-inch iron plate	15

$1\frac{1}{2}$-inch oak with a plate of $\frac{1}{8}$-inch iron in front, placed at an angle of 45° with the line of fire.

Plate I. Musket-balls glance off a mantlet thus placed.

Figs. 1 and 2 shew a method of attaching a mantlet to the rear axle of a pontoon carriage, so as to afford cover in placing a charge of gunpowder against a stockade or barrier. A gun limber or cart wheels and axle might be similarly fitted for the purpose. P P are pivot-bolts, on which the mantlet turns, passing through holes in the wrought iron stanchions, which fit into the sockets in the bolster of the carriage.

The mantlet can be raised on arriving at the stockade, by means of the rope in rear, so as to allow of the powder being placed against it with security.

The powder should be placed on the perch.

Additional security may be obtained by nailing a couple of raw hides on each wheel; and a fascine may be hung, as at F, fig. 1, to cover the feet of the men working the mantlet.

* By Captain Robertson, R. E.

Method proposed by Captain Robertson Royal Engineers, for adopting the perch and hind wheels of a Pontoon Waggon, to carry a Mantlet to give cover in placing a charge of Gunpowder against a Stockade.

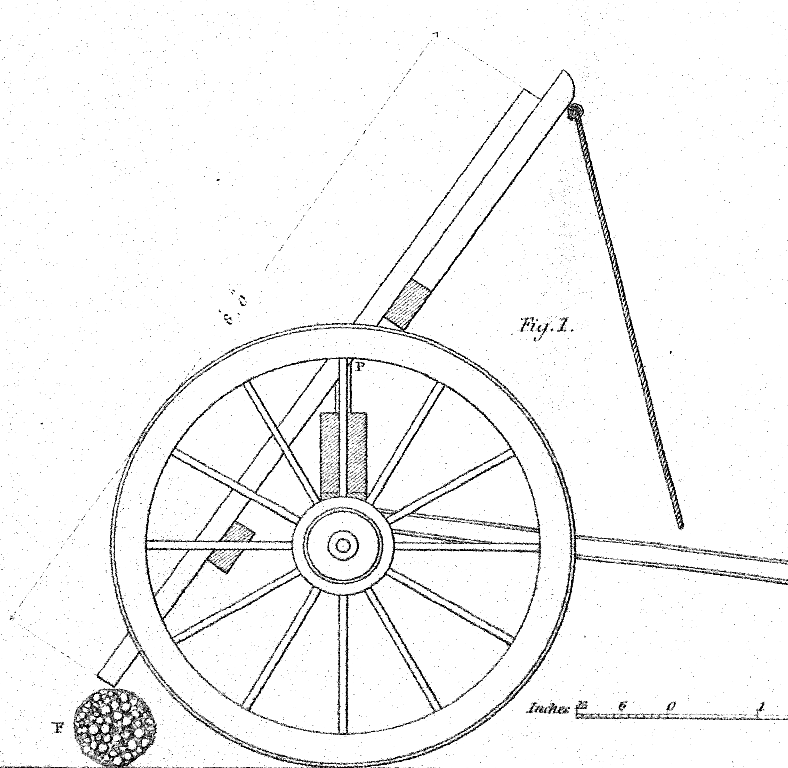


Fig. 1.

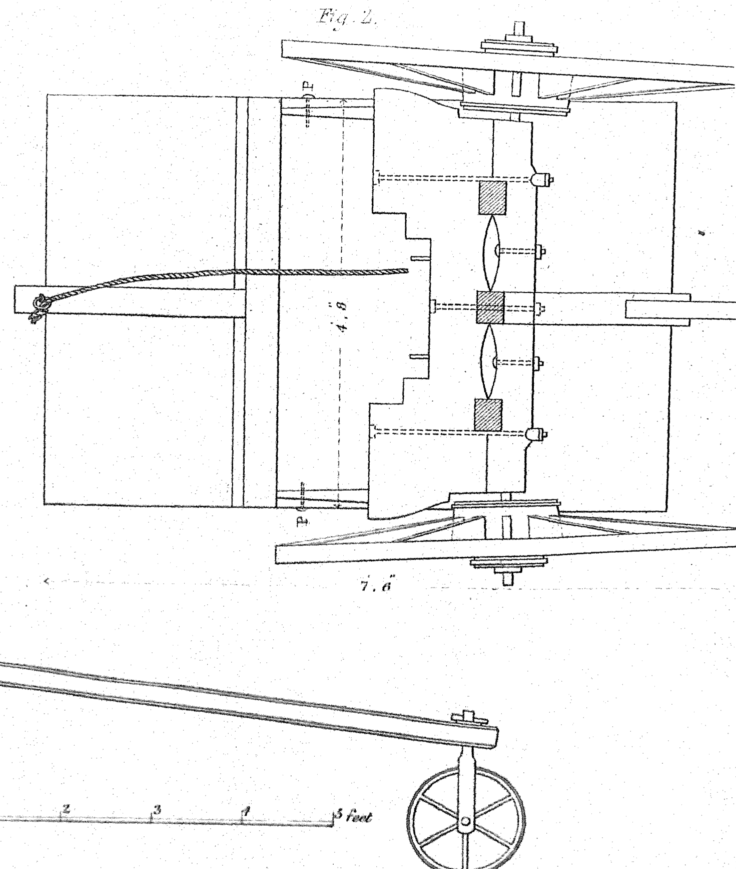


Fig. 2.

J.W. Lowry fc.

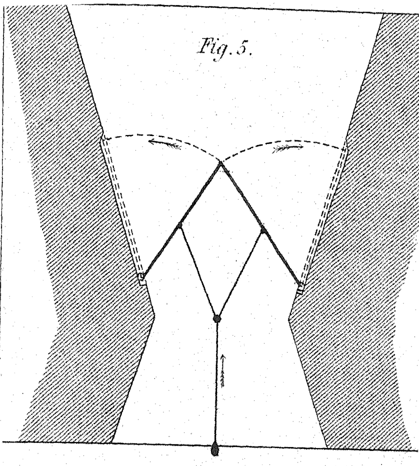


Fig. 5.

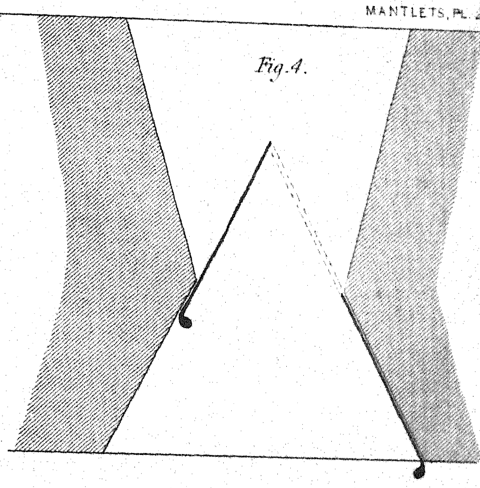


Fig. 4.

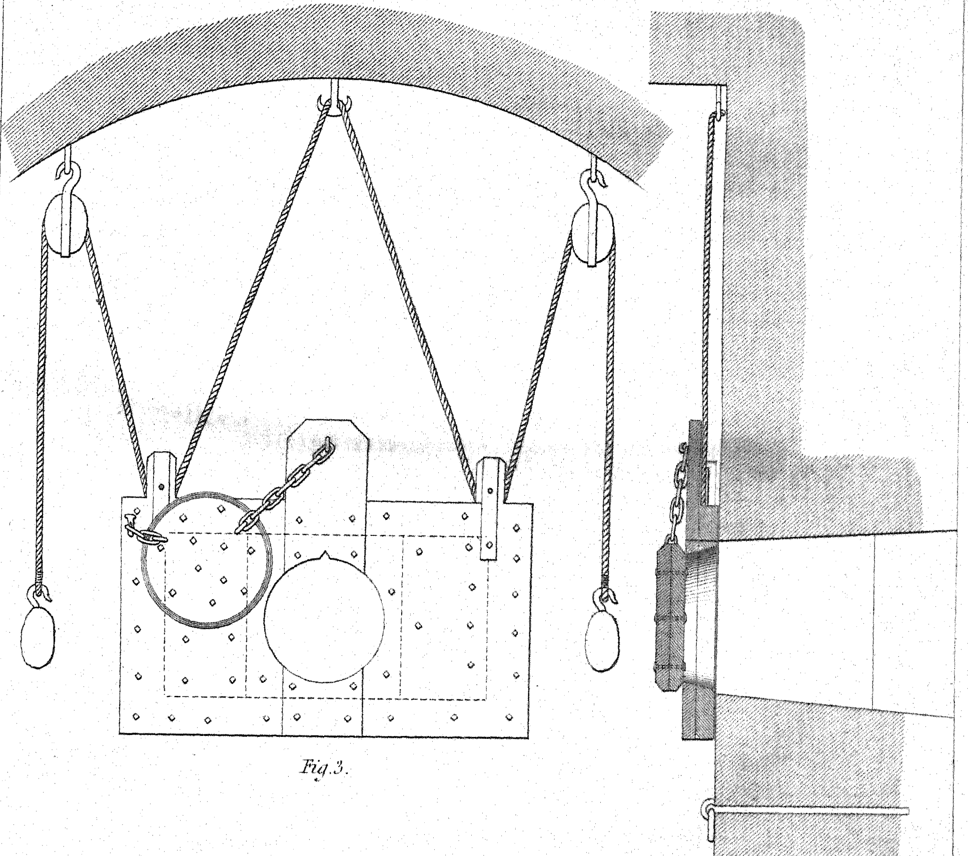


Fig. 3.

Inches 12 6 0 1 2 3 4 5 Feet

J. W. Lowry fc.

London John Weale, 59, High Holborn, 1848.

Fig. 3 shews the mode of hanging mantlets in casemates adopted by the Prussians.

Fig. 4, a form of mantlet applicable to embrasures, either in casemates or in parapets.

N.B.—In masonry embrasures a mantlet might, it is conceived, be placed, consisting of two musket-proof shutters on hinges, (*vide* fig. 5, Plate II.,) which, when opened, would serve to protect the masonry of the cheeks of the embrasures from injury by the discharge of the gun.

MARINE ARTILLERY.*—The Royal Marine Artillery, formed by Order in Council, 18th August, 1804, consisted of three companies, to which a fourth was added in 1805.

The principal destination contemplated for the Marine Artillery, as recited in the Order in Council, appears to have been for service in bomb-vessels, and to instruct the other part of the corps of Royal Marines in the exercise of guns.

In 1806, the Marine Artillery completed at Land-Guard Fort, by extensive experiments, Tables of Ranges for 13 and 10-inch sea-service mortars, the use of which ordnance was especially assigned to this corps. Circumstances extended the services of the Marine Artillery, who were now, besides bomb-vessels, mortar-boats, gunboats, and rocket-boats, employed with heavy and field artillery in desultory debarkations, and other cases at sieges, and more permanently on shore.

A Professor of Mathematics was attached to the Marine Artillery, under whose instruction the Officers passed through a course similar to that at the time pursued at Woolwich.

After the war, a Laboratory of Instruction was added, which indeed includes those usually denominated Repository Instructions, as well as those of the laboratory, essential to be known by artillerymen on service. At the termination of the war, the Marine Artillery was increased to eight companies. In 1832 they were reduced to two companies. Several augmentations subsequently took place; and in June, 1847, the Marine Artillery was increased to ten companies; giving a total of numbers, including Officers, of 1503.

The annexed Table will shew the strength of the Marine Artillery at its formation; also the periods and amount of the principal reductions and augmentations it has undergone.

The Officers selected for the Marine Artillery companies are now educated at the Royal Naval College at Portsmouth.

It is probable the great extension of steam navigation, which has in several respects indicated new wants, has influenced the increase of marine artillery; since, if furnished with strong detachments of marine artillery in each vessel, large numbers of merchant steamers, with seamen even untrained to artillery exercises, can quickly be converted into steam ships of war, on any sudden outbreak of hostilities.

* By Major Stevens, Royal Marine Artillery.

THE ROYAL MARINE ARTILLERY.

	Lieutenant-Colonel.	Major.	Captains.	1st Lieutenants.	2nd Lieutenants.	Adjutants.	Quarter-Master.	Barrack-Master.	Surgeon.	Assistant Surgeon.	Serjeant-Major.	Quarter-Master Serjeant.	Barrack-Serjeant.	Serjeants.	Corporals.	Bombardiers.	Drummers.	Gunners.
First Establishment, Three Companies, 18th August, 1804.			3	9	15									15	15	24	9	186
Four Companies, 2nd August, 1805.			4	12	20									32	20	32	12	248
Eight Companies, January, 1817.	1	1	8	16	16	1	1	1	1	1	1	1	1	48	32	48	16	480
Four Companies, 10th March, 1831.		1	4	5	8	1	1	1			1		1	20	20	12	12	316
Two Companies, 1832.			2	4	4						1			12	12	6	6	186
Ten Companies, 1847.	1		11	19	20	1					1			70	70	30	30	1250

The pay of the Marine Artillery Companies is the same with that in corresponding ranks in the Royal Regiment of Artillery.

Non-commissioned officers and gunners of Marine Artillery, when at sea, have a sum deducted for their rations, as marines have, not the same, but which bears a like ratio to *their* pay, as that which is deducted from the Royal Marines under the same circumstances, *does to their pay.*

The duties of the Marine Artillery Companies are nowhere defined by any express order, except the Order in Council alluded to.

But they are expected and required to be acquainted with the service of every kind of artillery afloat.

Also to undertake the same on shore, whenever this extension of their duties may be deemed necessary for H. Majesty's Service.

Nor is their service restricted to any nature of vessel. At this moment there is a subaltern's detachment embarked in the Commander-in-Chief's ship in the Pacific, and, with one or two exceptions, a detachment in each steamer.

In common with the other part of the Royal Marine Corps, their pay and accounts, when embarked, are entirely managed by the Paymaster and Purser of the ship in which they embark.

The head-quarters of the Royal Marine Artillery, at its formation, were with the head-quarters of the division of Royal Marines at Chatham.

In 1819, their head-quarters were removed to Fort Monckton, near Gosport. In 1822, the Marine Artillery were sent as a temporary measure to the Upper Barracks at Chatham, in consequence of fever and ague having broken out to a great extent in the corps, attended by glandular affections, at Fort Monckton.

In 1824, the Marine Artillery moved to Portsmouth.

SERVICES.

The early services of the Marine Artillery, during the war, were in bomb-vessels, for which this corps was especially formed; but these were soon extended to gun,

mortar, and rocket-boats; and by the natural exigencies of war, to the usual artillery duties on shore, in the field, in garrison, and at sieges. In 1805, they were employed in bomb-vessels, chiefly under Sir Edward Owen, on the coast of France, in opposing the transit of the flotilla of invasion from one port to another—in bomb-vessels, at the passage of the Dardanelles, 1807—at the bombardment of Copenhagen, 1807—Bay of Rosas—at Basque Roads—bombardment of Flushing, 1809—in garrison, at the defence of Anholt—at Cadiz, during the long blockade or siege—at the defence of Tarifa, afloat—on the N. Coast of Spain, under Sir Home Popham, 1811—in the Chesapeake, 1812—on the Island of South Beveland, with battery in the field—at New Orleans—in Canada, at sieges and attacks, as Fort Erie, Fort Oswego, &c.—at the bombardment of Algiers—on the N. Coast of Spain, under Lord John Hay—in the Parana, and in numerous minor operations.

Note.—That the whole of the Royal Marine Artillery should be at Portsmouth when not afloat, now augmented to 1500 men, appears unnecessary, as this station is not adequate to the increasing wants of the Naval Service for that important force, essential to the perfect equipment of Her Majesty's fleets.

For the future extension and organization of the Royal Marine Artillery, there are two improvements desirable:

First, to give every division its corps of Royal Marine Artillery.

Secondly, to assign to the Royal Marine Artilleryman a position afloat, corresponding with his importance and utility.

In respect to the *first proposition*, as the Marine Artillery is composed of men selected from the several divisions, and afterwards instructed in practical gunnery and laboratory duties, to qualify them to act afloat, much time would be saved in the subdivision of labour by having four stations instead of one; and each of the principal arsenals would always have the means of embarking their marine artillery, without sending to Portsmouth. This arrangement would likewise prevent any jealousy of the Portsmouth division on account of its having this Service attached to it ~~the division of Marines~~. The trifling additional expense in instructors is unimportant, compared to the advantages of facilitating the training and shortening the period of instruction.

The *second proposition*, rather startling by its novelty and apparent interference with the usages of the Naval Service, is merely, as expressed, to assign for the Royal Marine Artillery specific duties afloat, appropriate to the object of having them as a part of the equipment. The position of gunner or assistant-gunner is inapplicable to marine artillery, as those duties require men to be seamen, intrusted with the navigation of the vessel, and who are officers and petty officers, and take the responsibilities of command according to their rank.

It would seem necessary, to prevent confusion, to term the Royal Marine Artilleryman, when embarked on board Her Majesty's ships, *a bombardier*, and attach two or three bombardiers to every shell gun, of which every vessel has now a proportion equal to $\frac{1}{10}$th of her armament, and steam ships of war are chiefly armed with them.

Old sailors remark, that considerable danger exists in the introduction of shells afloat, particularly since the adoption of the concussion and percussion shells: this gives a force to the second proposition, of terming the Royal Marine Artillery, when embarked in ships of war, as *bombardiers*, and consequently of dropping that of *gunner*. It is true that seamen are instructed in practical gunnery, and are called naval gunners; but they are not permanently entered in the Service, and may not

be always forthcoming when wanted: hence the importance of a large marine artillery well instructed in laboratory duties.—*Editors.*

MARINE ARTILLERY OF FRANCE.*

The artillery or ordnance for the French Navy and for coast batteries is all of iron, in distinction to that used in the field, which is cast in brass for all calibres. The ordnance, whether for the armament of ships or for the defence of coasts, is termed Marine Artillery. The last regulation of 1840 directed them to be of the following dimensions:

8″ or 68-pounder } iron guns, } French measure.
6″ or 30-pounder }
Howitzers 8″
Mortars 12″

The 30-pounder guns are divided into long and short; but a larger proportion of the old patterns remain in the French Service.

The personel of the Marine Artillery of France has undergone several modifications from time to time: during the Empire it was employed in the field, and this corps distinguished itself at the battles of Bautzen and Lutzen.

Latterly the Marine Artillery has been disconnected from the French Navy, arising out of disputes between the two Services,† and it has been organized for duties in the colonies under the Minister of Marine, which department has the administration of the French colonies.

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* From 'Le Dictionnaire de l'Armée de Terre.'

† In the British Navy this is not likely to occur, as there can be no rivalry when one corps is dependent upon the other; but there is a similar tendency to unite and possess all the attributes connected with the naval duties, now divided between the Admiralty and the Ordnance Departments; that is, that the Navy should supply itself, and manufacture its guns, stores, and ammunition, and eventually execute the garrison and other duties connected with the coast defences.

This tendency, which may be by some deemed imaginary, has nevertheless manifested itself in various ways in our Service, under the view of facilitating the supply to the Navy, and the improvement of those articles furnished and manufactured by the Ordnance Department; but the change, it is conceived, if effected, will neither lead to economy nor to improvement in the armament of H. M. ships. An increased expense must of necessity follow the double establishments for the supply of guns, carriages, ammunition and stores, now furnished and manufactured by the Ordnance for the Army and Navy.

In respect to improvements likely to occur in the nature of the supply, considering the little advance in the art of gunnery during the last sixty years by the numerous alterations in the construction of artillery, and the proneness of Officers of the Navy to arm their vessels according to their own theory, we are inclined to believe that the ordeal of the Committee at Woolwich is an essential advantage to the efficient armament of ships of war.—*Editors.*

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